LANDSAT DATA CONTINUITY MISSION

LDCM Operational Land Imager Requirements Document

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM Foreword

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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1 Introduction

1.1 Scope

The Operational Land Imager Requirements Document (OLI-RD) establishes the Level 3 procurement requirements for the reflective band sensor for the Landsat Data Continuity Mission (LDCM). As a level 3 document, it contains the functional and performance requirements.

1.2 Mission Overview and Requirements Flow

The OLI provides Landsat multi-spectral image acquisition. The inherent goal of the OLI is to serve as a "standard Operational Land Imager" which will be integrated on the LDCM observatory.

OLI will be required to operate nominally on the observatory acquiring multi-spectral scenes (180km x 185km) on a 16 day repeat cycle, on the Worldwide Reference System - 2 with a descending node of 10:00am at a nominal orbit altitude of 705km at the equator. Mission Data will be collected over time intervals selected by the Flight Operations Segment. The mission data is either stored, real-time telemetered or both concurrently.

When this document states a requirement for the OLI to collect scenes, this shall be interpreted to mean that the OLI instrument shall collect imagery intervals sufficient to produce the scenes. The WRS-2 Scenes are actually generated as part of the Data Processing and Archive Segment after the data has been sent back to the United States Geological Survey/ Earth Resources Observation and Science (EROS) facility in Sioux Falls, South Dakota. The quality of the image data returned and processed at the EROS facility forms one of the many steps for determining if requirements have been successfully meet. See the LDCM Operations Concept Document, GSFC 427-02-02 for a more complete discussion of the LDCM operations.

To ensure that the imagery data collected by the OLI is of sufficient quality to produce calibrated and registered Landsat data products, the OLI contractor is required to demonstrate the production of calibrated and registered WRS-2 scenes on the ground using OLI data, contractor-developed data processing algorithms, and government-provided support data to correct residual errors in the LDCM data so that the resulting corrected LDCM data meet the imagery requirements of sections 5.6 and 5.7. The requirements of sections 5.6 and 5.7 presume that spacecraft bus performance is compliant with the Observatory Interface Requirements Document, GSFC 427-02-03.

The general structure of the LDCM Program requirements is shown in Figure 1.2-1. The flow down represented in this figure identifies which organization controls a set of requirements and who has the authority to change those requirements.

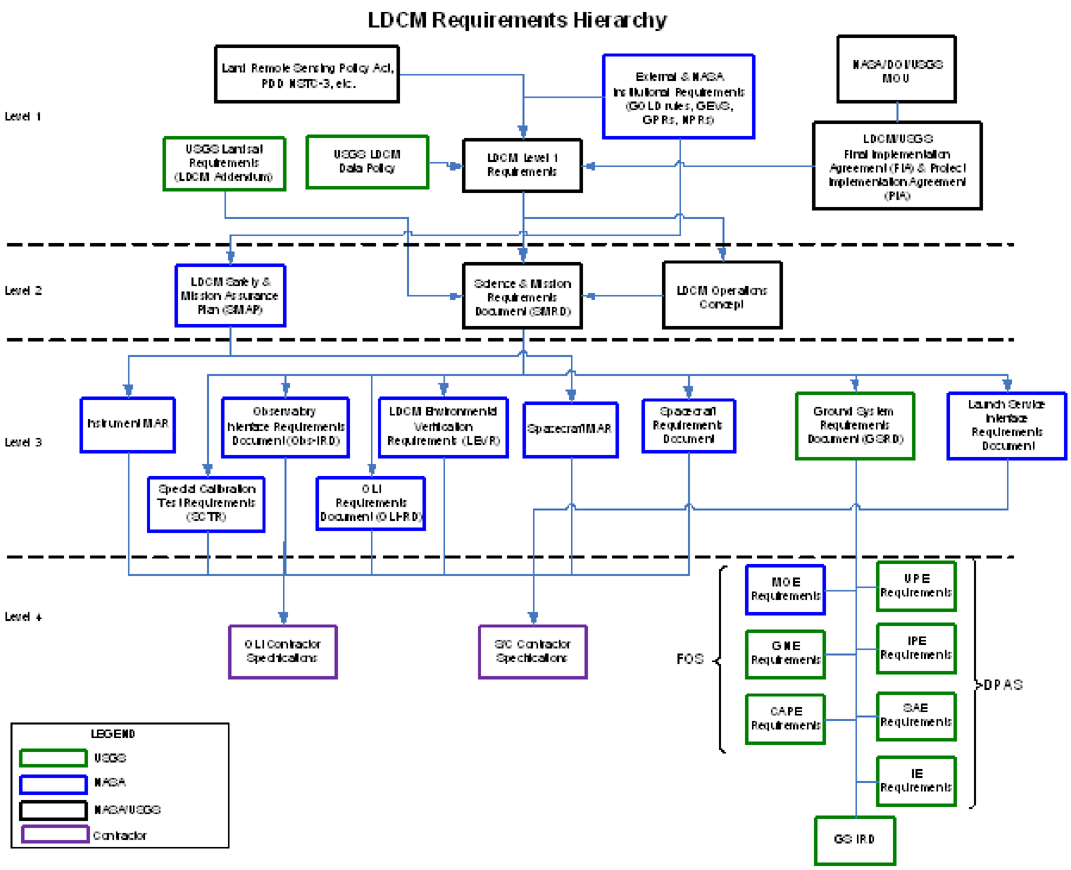


Figure 1 - 1 LDCM Requirements Flow

2 Applicable and Reference Documents

2.1 Applicable Documents

The OLI-RD is consistent with, and responsive to, the following applicable documents of the revision and release date shown.

Table 2 - 1 Applicable Documents

Document Number	Revision/ Release Date	Document Title
AFSPCMAN 91-710 (Vol. 1-7)	July 1, 2004	Air Force Space Command Manual 91-710 Range Safety User Requirements
CCSDS 133.0-B-1	September 2003	Recommendation for Space Data Systems Standards TM Space Packet Protocol. Blue Book. Issue 1.
CCSDS 231.0-B-1	September 2003	Recommendation for Space Data Systems Standards. TC Synchronization and Channel Coding. Blue Book. Issue 1.
CCSDS 232.0-B-1	September 2003	Recommendation for Space Data Systems TC Space Data Link Protocol. Blue Book. Issue 1.
CCSDS 232.1-B-1	September 2003	Recommendation for Space Data Systems Standards. Communications Operations Procedure-1. Blue Book. Issue 1.
CCSDS 301.0-B-3	January 2002	Time Code Formats
GSFC 500-PG-8700.2.2	Feb. 01, 2005	Electronics Design and Development Guidelines
KNPR 8715.3		KSC Safety Requirements
CLSB-0409-1109	Revision 10a, January 2007	ATLAS Launch System Mission Planner's Guide
NIMA TR8350.2	3rd Edition, Amendment 1, dated 3 January 2000	Department of Defense World Geodetic System 1984
NASA STD-5005	Rev. B, Sept. 15, 2003	Ground Support Equipment
NPD 8010.2	Rev. D, May 14, 2004	Use of the SI (Metric) System of Measurement in NASA Programs
NPD 8710.3	Rev. B, April 28, 2004	NASA Policy for Limiting Orbital Debris Generation
NPR 2810.1A	May 16, 2006	NASA Procedural Requirement, Security of Information Technology

2.2 LDCM Documentation

The OLI-RD is consistent with the following documents. Unless otherwise stated in this document, all inconsistencies in the OLI-RD will be resolved as defined in the OLI Statement of Work section IV.

Table 2 - 2 LDCM Documents

Document Number	**Document Title**
GSFC 427-02-01	Science and Mission Requirements Document
GSFC 427-05-01	OLI Statement of Work
GSFC 427-03-03	Instrument Mission Assurance Requirements
GSFC 427-02-06	LDCM Acronym List and Lexicon
GSFC 427-03-05	LDCM Environmental Verification Requirements (LEVR)
GSFC 427-02-02	LDCM Operations Concept Document
GSFC 427-05-04	Special Calibration Test Requirements (SCTR)
GSFC 427-02-07	LDCM Worldwide Reference System-2 Memorandum
GSFC 427-04-01	Top of Atmosphere Radiance Values Assessment
GSFC 427-08-01	Launch Services - Interface Requirements Document

2.3 Literature References

For additional clarification reference is made to documents in the open literature. These documents should be used for clarification and understanding of the requirement. These documents do not constitute additional requirements on the bidder.

Authors	**Document Number**	**Revision/ Release Date**	**Document Title**
[1] S. K. Park and R. A. Schowengerdt,		1983	"Image reconstruction by parametric cubic convolution," Computer Vision, Graphics, and

			Image Processing, vol. 23, pp. 258-272.
[2] A. Berk, G.P. Anderson, P.K. Acharya, J.H. Chetwynd, L.S. Bernstein, E.P. Shettle, M.W. Matthew, and S.M. Adler-Golden	01731-3010	1 June 1999	MODTRAN4 User's Manual, Air Force Research Laboratory, Space Vehicles Directorate Air Force Materiel Command, Hanscom AFB, MA

3 Functional Overview

The Operational Land Imager (OLI) contractor is required to provide the Landsat multi-spectral instrument for integration onto the LDCM spacecraft. The OLI is to perform for a period of 5 years within the prescribed requirements. The OLI is a nine band reflective sensor providing Visible and Near Infrared / Short Wave Infrared (VNIR/SWIR) imagery consistent with Landsat spectral, spatial, radiometric and geometric qualities as specified in Section 5 of this document. Terms used in this document may have unique meaning to the LDCM Project and are defined in the LDCM Acronym List and Lexicon, GSFC-427-02-06.

The OLI includes the optical telescope, Focal Plane Array / Focal Plane Electronics (FPA/FPE) and instrument control electronics. The optical telescope includes the optical bench assembly, baffles and mirrors to gather and focus the optical beam onto the FPA. The FPA/FPE converts photon energy into electrical voltage signals and converts the voltage signals into digital signals. The OLI is specified to provide nine spectral bands with a maximum ground sampling distance, both in-track and cross track, of 30m for all bands except the panchromatic band, which is specified to have a 15m ground sampling distance. The OLI will have a 185-km cross track swath width as measured at the equator at an orbital altitude of 705-km. The LDCM Observatory will operate in a nominal mission orbit of 716 ± 12 km altitude at 98.2 ± 0.15° inclination, sun synchronous, with a line of apsides and eccentricity that produces a “Frozen Orbit”. The LDCM Observatory will implement a yaw compensation maneuver to account for earth rotation effects on the image ground track. The OLI provides both internal calibration sources such as lamps to ensure radiometric accuracy as well as capabilities to perform solar and lunar calibrations within the field of view constraints. The on-board electronics provide the necessary band ordering and optional data compression necessary to meet the total data rate and data volume of the OLI.

The OLI will produce image data and instrument ancillary data. The image and instrument ancillary data will be combined with observatory ancillary data to create Mission Data. Observatory ancillary data includes such items as spacecraft attitude, navigation, timing data and key telemetry values from sensors and spacecraft. Ancillary data provide all necessary image reconstruction information for later ground processing.

4 OLI System Level

4.1 General

OLI-149 The LDCM OLI shall comprise of the sensor module, all associated sensor control electronics and power modules, all required control, signal processing and data formatting and compression electronics, and all hardware and software required to meet sensor performance requirements.

The LDCM OLI shall meet the requirements of the LDCM Observatory Interface Requirements Document, GSFC 427-02-03.

For an LDCM OLI design employing data compression or detector output aggregation, upon command, the OLI shall selectively disable any on-orbit processing operation that combines or compresses raw image or ancillary data in any manner. For compliance with this requirement, bit truncation of image data to 12 bits is not considered a data compression algorithm.

OLI-153 The LDCM OLI shall meet LDCM imaging requirements at all points throughout the orbit.

Rationale: Take an image anywhere within the orbit sunlit or eclipse.

OLI-155 The LDCM OLI shall acquire image and ancillary data equivalent to produce 400 non-contiguous WRS-2 Scenes, including the on-orbit calibration data, over any 24 hour period.

Rationale: The LDCM OLI will be capable of acquiring sensor image data equivalent to 400 WRS-2 scenes per day plus any necessary calibration data. The 400 WRS-2 scenes account for all image collections in a 24-hour period. Vicarious calibration images are part of the 400 WRS-2 equivalent scenes. On-orbit calibration data will include lunar, solar, internal sources and is in addition to the 400 scenes. The WRS-2 scenes are actually generated on the ground and not on-orbit.

OLI-157 The LDCM OLI shall operate within the designed operational parameters when the LDCM Observatory points up to 15 degrees, off-nadir, to either side of the current orbit plane.

Rationale: The OLI instrument must remain thermally stable, and fully function in off-nadir pointing attitudes. The image acquisition in this attitude is in lieu of an equivalent amount of nadir WRS-2 path image acquisition.

OLI-159 The LDCM OLI shall acquire up to 5 off-nadir image intervals per day as part of the 400 WRS-2 equivalent OLI image and ancillary data.

Rationale: For rapidly changing conditions on the Earth, LDCM will be able to image either WRS-2 scenes or off-nadir scenes. These may or may not be a priority interval.

OLI-161 The LDCM OLI shall acquire up to 77 contiguous, sun-lit scenes during any orbit.

Rationale: See the design reference missions in the Operations Concept document which provides the longest possible daylight contiguous land pass. The WRS-2 scenes are actually generated on the ground and not on-orbit.

OLI-163 The LDCM OLI shall acquire up to 38 contiguous, night scenes during any orbit.

Rationale: See the design reference missions in the Operations Concept document which provides a possible lunar imaging scenario for calibration using the moon. The WRS-2 scenes are actually generated on the ground and not on-orbit.

OLI-165 The LDCM OLI shall be commanded by the ground into any operational mode.

Rationale: Operational flexibility but also should not be possible to command the instrument into non-operational (ground test, storage, etc.) modes.

OLI-167 The LDCM OLI documentation shall be in compliance with NASA Policy Directive 8010.2, Use of the SI (Metric) System of Measurement in NASA Programs.

4.2 OLI System Lifetime

OLI-169 The LDCM OLI shall be designed to operate and meet all design specifications for 5 years beginning at Government on-orbit acceptance of the OLI.

Rationale: Design life starts after acceptance, so instrument commissioning is in addition to the 5 years of operations. Performance margin must be applied to the design requirements to ensure 5-year life still meets the stated performance requirements.

OLI-171 The LDCM OLI shall be designed for an overall Probability of Mission Success of 0.85 or greater at the end of design life.

Rationale: End of design life Mission Success is defined as meeting 100% of the OLI requirements at the end of the instrument design life.

4.3 Mission Phases

4.3.1 Ground Storage Phase

OLI-175 The LDCM OLI shall have a non-operational ground storage state that does not require intervention by personnel for 30-day periods.

Rationale: This requirement allows for storage of the instrument in the event of delays. This requirement does not preclude the use of nitrogen or some other purge gas during storage to ensure cleanliness and maintain nominal humidity. This requirement does not preclude safety monitoring of hazardous systems if required by the MAR.

4.3.2 Pre-Launch Phase

The LDCM OLI shall be designed for a launch from Vandenberg AFB, CA.

The LDCM OLI shall be compatible with a government furnished payload processing facility at Vandenberg AFB, CA.

OLI-181 The LDCM OLI shall function in an ambient environment to facilitate functional testing.

Rationale: Though performance testing is likely to require flight like conditions, aliveness and function performance, along with power up and down operations should be done in ambient conditions whenever possible.

OLI-183 The LDCM OLI and its Ground Support Equipment used at the launch site shall comply with the US Air Forces Space Command Manual 91-710 Range Safety User Requirements, dated July 1, 2004.

Rationale: Any hazardous systems on the OLI must be in compliance with the Western Range. This includes the use of pyrotechnics, pressurized systems, radiation sources, mechanical lift equipment, electrical equipment, etc.

OLI-185 The LDCM OLI shall be designed to be compatible with the Atlas V, Model-401 launch vehicle.

Rationale: The OLI must meet all performance specifications after exposure to the environments associated with launch on this vehicle. Though launch environments will be attenuated and/or amplified by the S/C structure.

OLI-187 The LDCM OLI shall be compatible with the cleanliness specified in GSFC 427-08-01, Launch Services - Interface Requirements Document.

Rationale: The OLI must meet all performance specifications after exposure to the environments within the launch vehicle fairing. If special protection is required it is the responsibility of the OLI contractor to provide that protection.

OLI-189 The LDCM OLI shall perform aliveness tests while mated to the launch vehicle.

Rationale: To ensure the instrument is ready for launch, on pad testing will be performed.

4.3.3 Launch and Early Orbit Phase

OLI-192 The LDCM OLI shall remain in the Survival Mode during Launch and Early Orbit Phase of the mission.

Rationale: OLI operations should not interfere with the initial turn-on of the observatory; therefore there should be no need for checking the OLI during the first week of the mission.

OLI-194 The LDCM OLI, once fully integrated within the LDCM observatory, shall not have any instrument constraints to attempting a launch once every 24 hours, including every 24 hours after the initial launch attempt.

Rationale: To support a launch opportunity every day of the year there should not be any instrument constraints to attempting a launch once every 24 hours.

OLI-196 The LDCM OLI, once fully integrated within the LDCM observatory, shall remain ready for launch with no required servicing (other than a gaseous purge) for at least 7 days.

Rationale: Unforeseeable rocket, Observatory, and range conditions can delay launch. There is no access to OLI during this time. This requirement does not preclude the use of conditioned air or purge gas.

4.3.4 Commissioning Phase

OLI-199 The LDCM OLI shall require no more than 60 days to complete commissioning activities once the observatory is ready to begin OLI commissioning.

Rationale: This requirement is an allocation of the 90 days for observatory commissioning. It is anticipated that the S/C will finish within 30 days, though it may not have achieved mission orbit.

4.3.5 Operational Phase

Reserved

4.3.6 Decommissioning Phase

OLI-204 The LDCM OLI shall be compliant with NASA Policy Directive NPD 8710.3, NASA Policy for Limiting Orbital Debris Generation.

Rationale: The NPD provides guidelines for minimizing orbital debris. It also invokes NASA Safety Standard NSS 1740.14 for assessing debris and mission survivability. Aperture covers, doors, etc. will not be released as orbital debris and material selection will consider the effects on the re-entry foot print.

4.4 Operational Orbit

OLI-207 The LDCM OLI shall meet performance requirements when in the mission nominal orbit of 716 ± 12 km altitude and 98.2 ± 0.15° inclination.

Rationale: The WRS-2 orbit will be used by the LDCM Observatory. OLI's performance may be evaluated at any point in the orbit based on this reference system.

4.5 Redundancy Requirements

OLI-210 The LDCM OLI requirements identified in section 4.5 shall only apply to redundant systems.

OLI-211 The LDCM OLI shall be designed such that no single credible failure permanently precludes the LDCM from meeting the mission requirements throughout the OLI design life.

OLI-212 The LDCM OLI shall have no single command that could cause the loss of OLI, assuming no previously failed OLI components.

OLI-213 The LDCM OLI shall provide the status of powered redundant components following a processor restart, a processor failover, RAM memory loss, or bus under-voltage.

Rationale: This is to prevent the instrument from automatically switching to previously failed components.

OLI-215 Upon command, the LDCM OLI shall switch from the prime to the backup unit for redundant systems.

Rationale: This allows switching back and forth between prime and backup units through ground commands.

OLI-217 Upon command, the LDCM OLI shall switch from the backup to the prime unit for redundant systems.

Rationale: This allows switching back and forth between prime and backup units through ground commands.

OLI-219 The LDCM OLI shall provide status telemetry for all powered redundant systems.

OLI-220 The LDCM OLI shall provide indication in housekeeping data which component of a redundant system is operating.

4.6 Autonomy

OLI-222 The LDCM OLI shall operate safely on orbit without ground intervention for periods up to 16 days duration.

Rationale: In the event there is a failure the OLI can safe itself including powering off if necessary. There might not be an imaging schedule but the instrument would survive.

OLI-224 The LDCM OLI shall autonomously perform reconfiguration of redundant components or employ secondary measures to safeguard the instrument should the primary means of achieving Safe Mode not be achieved.

Rationale: If Safe Mode cannot be achieved through the primary pathway, the instrument should autonomously employ redundant or secondary measures to protect the internal optical and focal plane components. The diffuser, although sensitive to contamination and solar flux, offers a reasonable backup method of protecting the internal telescope components in an emergency situation.

The LDCM OLI shall not autonomously switch to a known failed redundant component.

OLI-228 Upon command, the LDCM OLI shall override autonomous functions, automatic safing, or switchover.

Rationale: This permits diagnosis of failures and anomalies within the instrument via ground command.

OLI-230 The LDCM OLI shall report autonomous state changes and reconfigurations in housekeeping telemetry.

OLI-231 The LDCM OLI autonomous reconfiguration of redundant systems, or autonomous employment of secondary measures, shall be limited to steps necessary to safeguard the instrument.

Rationale: It is prudent to limit autonomous reconfigurations or autonomous use of secondary measures to situations in which the instrument is at risk of catastrophic harm.

OLI-233 The LDCM OLI shall, in the event of an anomaly, safely configure the instrument and report the anomaly to the ground in telemetry.

OLI-234 The LDCM OLI autonomous operations shall be performed from on-board software.

Rationale: To prevent stored command queues from causing a problem or the need for multiple conditions to be successful outside of a processor. All autonomous operations should be from code and not stored commands.

4.7 Availability

OLI-237 The LDCM OLI shall be available for collecting image data that meets the OLI requirements at least 95% of the time during a WRS-2 Observation Period. The instrument is considered unavailable for times in which either: 1) the instrument is not meeting performance requirements, or 2) the instrument is performing calibration or maintenance procedures necessary for satisfying performance requirements. By definition, the instrument is considered available for all other times.

OLI-239 Upon receipt of a valid command, the LDCM OLI shall successfully execute 99.9375% of scheduled scene acquisitions over any 16 day observation period.

Note: This requirement applies to execution only. It does not apply to anomalies affecting availability (addressed by OLI-237) nor to compliance with performance requirements.

Rationale: This produces a 1-scene loss in 4-days of imaging when the instrument is in Operational Mode.

4.8 Ground Support Equipment

OLI-242 The LDCM Ground Support Equipment (GSE) designed and built or procured under a LDCM contract shall comply with NASA-STD-5005 Ground Support Equipment.

OLI-243 The OLI GSE shall consist of the following:

- OLI Interface Simulator (OIS)
- System Test Equipment (STE)
- Calibration Test Equipment (CTE)
- Handling and lifting fixtures
- Test fixtures including imaging targets
- Shipping / storage containers

OLI-250 The LDCM OLI GSE shall provide an interface to OLI System Test Equipment for real-time data capture and recording of data as received from and transmitted to the LDCM spacecraft.

4.8.1 OLI Interface Simulator

OLI-252 The LDCM OIS shall simulate the OLI response to hardware or discrete commands and commands received across the communications bus.

Rationale: The OLI I/F simulator should respond in a manner like the flight OLI for commands that do not come through command communication bus.

OLI-254 The LDCM OIS shall generate realistic response characteristics for analog telemetry, housekeeping telemetry and image and ancillary data.

OLI-255 The LDCM OIS shall provide an electrical load consistent with the interface control document between OLI and the LDCM Spacecraft.

Rationale: To provide response characteristics to the spacecraft during power on testing.

OLI-257 The LDCM OIS shall generate internal timing response from LDCM Spacecraft timing signals, 1-pulse per second, and time of day messages consistent with the interface control document between OLI and the LDCM Spacecraft.

Rationale: To provide response characteristics to test spacecraft and instrument timing.

OLI-259 The LDCM OIS shall provide a MIL-STD-1553 remote terminal interface to validate messages exchanges between the OLI and LDSM Spacecraft consistent with the interface control document between OLI and the LDCM Spacecraft.

Rationale: To provide testing of the 1553 interface characteristics between spacecraft and instrument.

OLI-261 The LDCM OIS shall provide data flow over the High Speed Science Data Bus consistent with the interface control document between OLI and the LDCM Spacecraft.

Rationale: To provide testing of the of the high-speed data interface characteristics between spacecraft and instrument.

OLI-263 The LDCM OIS shall provide responses to bi-level (both states) inputs consistent with the interface control document between OLI and the LDCM Spacecraft.

Rationale: To provide testing of the of the bi-level command interface characteristics between spacecraft and instrument.

OLI-265 The LDCM OIS shall provide a flight-like OLI instrument electrical interface connection for mating to the LDCM Spacecraft.

Rationale: The OIS will mate to the S/C to test electrical interface. This may actually require multiple connectors to complete the electrical connection.

OLI-267 The LDCM OIS shall operate using OLI flight software and databases.

OLI-268 The LDCM OIS shall be in compliance with LDCM MAR for connection to flight hardware.

Rationale: The OIS will be connected to the spacecraft bus to perform check-out of the S/C OLI interface before the flight instrument is shipped.

4.8.2 System Test Equipment (STE)

OLI-271 The LDCM OLI STE shall test all electrical interfaces between the OLI and the spacecraft including but not limited to power, clock, command, and telemetry.

OLI-272 Upon command, the LDCM OLI STE shall record, display, distribute, and analyze the data received from the OLI and ground support equipment including instrument test points.

OLI-273 Upon command, the LDCM OLI STE shall capture and time tag all data as received from the OLI and STE inclusive of image and ancillary data.

Rationale: Data capture permits post-test analysis and provides a historical record of all data that is generated during I&T activities.

OLI-275 Upon command, the LDCM OLI STE shall display real-time OLI housekeeping and diagnostic data.

OLI-276 Upon command, the LDCM OLI STE shall generate hard copy print out of all analysis results, screen dumps, and processed data.

OLI-277 The LDCM OLI STE shall generate data on, and receive data from, hard media (i.e., CD and/or DVD).

Rationale: Hard media addresses the need to use any industry typical, permanent media that allows for the mission lifetime storage of test and engineering data.

OLI-279 The LDCM OLI STE shall furnish all power, timing signals, and commands needed by the OLI and normally supplied by the spacecraft.

OLI-280 The LDCM OLI STE shall physically isolate all power lines from signal lines.

Rationale: To protect communication circuits from high voltage OLI should use shielded and separate cables.

OLI-282 The LDCM OLI STE power supplies shall have short-circuit protection and voltage-transient protection.

OLI-284 The LDCM OLI STE shall be able to perform a self-test.

OLI-285 The LDCM OLI STE shall be able to send commands to the OLI elements

OLI-286 The LDCM OLI STE shall be the able to control the simulated S/C interfaces and external calibration GSE

OLI-287 The LDCM OLI STE shall receive data from the OLI, STE, and supporting test equipment.

OLI-288 The LDCM OLI STE shall perform health and safety checks to guarantee the safety of the OLI elements and test equipment (in all states).

OLI-289 Upon command, the LDCM OLI STE shall analyze the data in real-time as well as in an off-line mode.

OLI-290 The LDCM OLI STE shall analyze and process image data, ancillary data, and instrument housekeeping data within 2 hours of collection, exclusive of the time required to collect the data.

OLI-291 The LDCM OLI STE shall process image and ancillary data within eight hours of collection, exclusive of the time required to collect the data.

OLI-292 The LDCM OLI STE shall include engineering, instrument data trending, and sensor data analysis tools.

Rationale: This will help determine instrument performance.

OLI-293 The LDCM OLI STE shall simultaneously operate and monitor the instrument, and perform data analysis.

OLI-294 The LDCM OLI STE shall display instrument engineering data as well as external GSE data.

OLI-295 The LDCM OLI STE shall display information corresponding to a set of pre-stored display templates.

OLI-296 The LDCM OLI STE shall display raw data in operator-selectable formats, including digital numbers (i.e. hexadecimal, integer, unsigned integer, etc.) and real values in SI units.

OLI-297 The LDCM OLI STE shall have an operator interface.

OLI-298 The LDCM OLI STE shall provide an interface with the OLI Calibration Test Equipment so that data will be entered into a data system and test correlated.

OLI-299 Upon command, the LDCM OLI STE shall monitor all command states, selected voltages, currents, temperatures, and other telemetered and derived parameters in real-time.

OLI-300 The LDCM OLI STE shall monitor any OLI deployments in real-time.

The LDCM OLI STE shall monitor any OLI pyrotechnic events in real-time.

OLI-302 The LDCM OLI STE shall automatically protect the instrument if appropriate operator action is not taken.

OLI-303 The LDCM OLI STE shall verify all operational modes of the OLI.

OLI-304 The LDCM OLI STE shall record and alert the operator of any out-of-tolerance items as they occur.

OLI-305 Upon command, the LDCM OLI STE shall bypass or terminate all automatic sequences resident in the instrument or in the LDCM OLI STE.

OLI-306 The LDCM OLI STE shall operate, at the first application of power during instrument integration and continuing through all periods of operation and/or test, a limits check program.

OLI-307 The LDCM OLI STE shall maintain a command and operational time log.

OLI-308 The LDCM OLI STE shall support on Ethernet I/O port for data sharing with the spacecraft ground support equipment.

4.8.3 Mechanical Ground Support Equipment (M-GSE)

OLI-310 The LDCM OLI M-GSE shall move and rotate the OLI.

OLI-311 The LDCM OLI M-GSE shall lift the OLI from and return it to its shipping/ storage container.

OLI-312 The LDCM OLI M-GSE shall provide support for the integration of the OLI onto the spacecraft.

OLI-313 The LDCM OLI M-GSE shall provide support for the performance verification, environmental testing and calibration of OLI.

4.8.4 Shipping/ Storage Containers

OLI-315 The LDCM OLI Shipping and Storage Containers shall be reusable, be water-resistant, be fire-resistant and contain a filered purge capability and a pressure relief system.

OLI-316 The LDCM OLI Instrument Shipping & Storage Container shall incorporate means of purging with dry nitrogen or dry air.

OLI-317 The LDCM OLI Instrument Shipping & Storage Container shall incorporate means of measuring and recording shocks, temperature and humidity within the container.

OLI-318 The LDCM OLI Instrument Shipping & Storage Container shall have external indicators for temperature and pressure monitoring and internal or external indicators for humidity monitoring.

OLI-319 The LDCM OLI Instrument Shipping & Storage Container shall be designed to maintain positive internal pressure while under purge for over 30 days.

OLI-320 The LDCM OLI Instrument Shipping & Storage Container shall maintain a positive pressure difference of at least 1.7 kPa between the container interior and the ambient exterior at all times while the OLI is within the container.

The LDCM OLI Instrument Shipping & Storage Containers shall be provided for all other OLI GSE transported to the spacecraft vendor or launch site.

The LDCM OLI Instrument Shipping & Storage Containers shall be suitable for use in the clean room, after a minimal amount of cleaning.

4.9 OLI Simulator

OLI-325 The LDCM OLI Simulator shall operate both mated to and independent from the LDCM Spacecraft Simulator.

Rationale: In support of diagnostics of the Flight OLI is may be necessary to run the OLI simulator “off-line” from the spacecraft. This functionality may also be useful for developing response characteristics in the simulator.

The LDCM OLI Simulator shall realistically simulate the OLI response characteristics appropriate to LDCM Spacecraft attitude changes, such that telemetry responses represent what would be received from the LDCM OLI in flight.

OLI-328 The LDCM OLI Simulator shall simulate the operations of the OLI command and data-handling system.

OLI-329 The LDCM OLI Simulator shall simulate the operations of the OLI power distribution system.

OLI-330 The LDCM OLI Simulator shall simulate the operations of the OLI telemetry and command response system.

Rationale: During FOT training for software updates, as applicable, the simulator should simulate the appropriate telemetry responses to commands.

OLI-332 The LDCM OLI Simulator shall simulate the nominal and diagnostic operations of the focal plane electronics.

Rationale: This should include generating/producing nominal image test patterns and diagnostic image data as is appropriate.

OLI-334 The LDCM OLI Simulator shall interface with the LDCM Spacecraft Simulator using all flight-like connections specified in the ICD.

Rationale: So that the OLI software simulator can talk to the S/C simulator without have to define a unique electrical and connector interface.

OLI-336 The LDCM OLI Simulator shall simulate all OLI operational modes and mode transitions.

OLI-337 The LDCM OLI Simulator shall verify valid OLI commands, table updates and flight software modifications.

OLI-338 The LDCM OLI Simulator shall receive commands in any flight valid format and data rate.

Rationale: Not anticipating variations if a 1553 interface is used, so this could be an easy requirement. However, if the meaning of discretes can change or if there are other ways to command the OLI then they should be modeled.

OLI-340 The LDCM OLI Simulator shall receive, process, and execute flight software updates that may include complete version updates, patches, and table updates, that are identical to updates for the flight OLI.

OLI-341 The LDCM OLI Simulator shall accurately simulate the timing of command responses.

OLI-342 The LDCM OLI Simulator shall generate real-time housekeeping telemetry streams with representative OLI data in all valid formats and data rates.

OLI-343 The LDCM OLI Simulator shall generate OLI image and ancillary data streams with representative data in all valid formats and data rates.

Rationale: This should include the effects of compression if present and without compression if turned off.

OLI-345 The LDCM OLI Simulator shall simulate the response characteristics of failed OLI subsystems and components.

OLI-346 The LDCM OLI Simulator shall simulate user-defined faults in the OLI.

OLI-347 The LDCM OLI Simulator shall respond to real-time operator changes in the configuration of the simulated OLI.

OLI-348 The LDCM OLI Simulator shall accept inputs from the user to set and change simulation variables.

Rationale: allows users to inject faults, vary initial conditions, etc.

OLI-350 The LDCM OLI Simulator shall accept inputs from the user to set and synchronize simulation time with observatory clock time and ground system time.

Rationale: To synchronize the events on-orbit with the events in the simulation

OLI-352 The LDCM OLI Simulator shall save both executed simulations and simulation data.

Rationale: This allows trainers to establish a baseline set of training simulations and to be able reproduce a simulation.

OLI-354 Upon command, the LDCM OLI Simulator shall run previously executed simulations.

Rationale: This allows trainers to establish a baseline set of training simulations and to be able reproduce a simulation.

OLI-356 The LDCM OLI Simulator shall operate using the OLI flight software, databases, constraints, limits, parameters, and metrics.

Rationale: The FOT will use the Simulator only as an on-orbit asset, and will have no knowledge nor experience with the OLI development or test environments.

4.10 Software Development and Verification Facility

OLI-359 The LDCM OLI Software Development and Verification Facility (SDVF) shall include Engineering Development Unit versions of the LDCM OLI command and data handling system, the power control/ distribution system and other hardware necessary to replicate the flight hardware needed for software development, verification, maintenance, and anomaly resolution purposes.

Rationale: The SDVF should consist of the proper hardware to accurately simulate OLI behavior for anomaly resolution, and to maintain and update reprogrammable flight software over an extended operational period of the mission.

OLI-361 The LDCM OLI SDVF shall be self contained and not require additional software or hardware to perform LDCM flight software development, verification, and maintenance.

Rationale: SDVF may consist of a suite of tools, compilers, de-buggers, performance assessment tools, etc. but should be all within one facility. These tools should remain under configuration control equivalent to the flight software.

5 Imagery Requirements

5.1 General

This section establishes the requirements for image characteristics and image quality to be provided by the Operational Land Imager. This section also describes the requirements for image correction that are necessary in order to verify Operational Land Imager performance. The LDCM OLI image requirements will only apply to nadir imaging. Off-nadir imaging is important to meeting LDCM mission requirements but they will not drive the instrument performance. The requirements on OLI concerning off-nadir are to ensure that the instrument design operates reliably and off-nadir does not influence the operational life of the instrument.

OLI-366 The LDCM OLI shall have a minimum field of view that provides a continuous 185-km wide cross-track swath width at the equator for the LDCM operational orbit except as stated in Section 5.6.7 Dead, Inoperable, and Out-of-Spec Detectors.

Rationale: The WRS-2 orbit has a nominal equatorial altitude of 705 km. Earth flattening causes the altitude of a circular orbit to vary from 705 km at the equator to just over 726 km at the maximum latitude. Designing the sensor to operate over a range of altitudes from 704 km to 728 km accounts for the effects of Earth flattening and a small amount (~1 km) of orbital variation.

OLI-1485 The LDCM OLI shall collect and transfer image and ancillary data to the LDCM Spacecraft Bus uninterrupted in the along-track data collection.

Rationale: The image intervals and supporting ancillary data, which may cover multiple WRS-2 Scenes, must be collected and transferred without data drops or missing detector readouts.

OLI-368 The LDCM OLI shall collect and transfer health and status data whenever power is applied to the instrument.

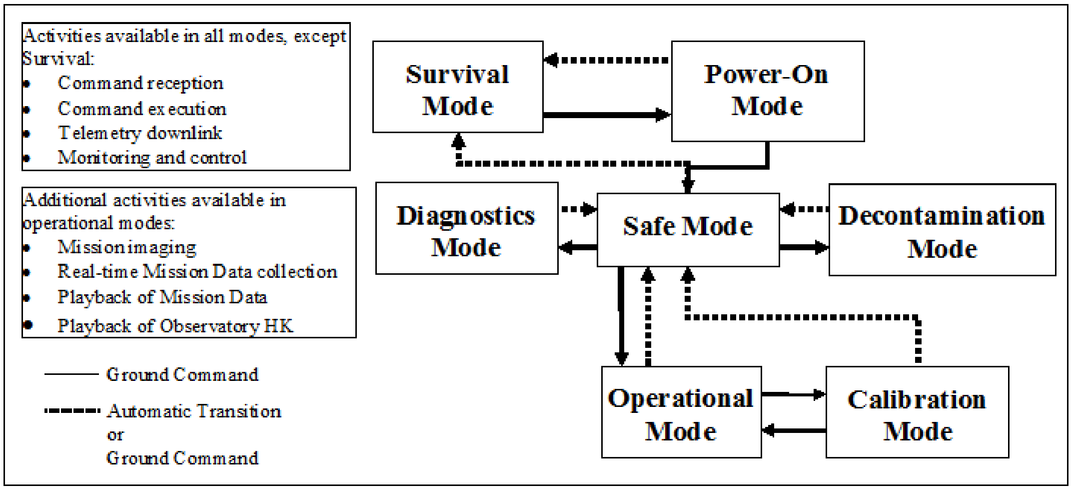
Rationale: Telemetry should be transmitted to the spacecraft whenever power is on the instrument.

5.2 OLI Operational Modes

OLI-371 The LDCM OLI contractor shall implement a mapping of the OLI modes to the following modes and functionalities, as defined herein.

Rationale: This document uses the following definition of OLI modes. However, the OLI contractor is not required to use these same definitions there needs to be a mapping of these modes to the contractor modes.

Figure 5 - 1 OLI Modes Transition Diagram



5.2.1 Survival Mode

OLI-376 The LDCM OLI shall implement an Instrument Survival Mode.

Rationale: Survival Mode is entered when the spacecraft has identified a critical power shortage. The OLI instrument will be reactivated by ground command post spacecraft recovery.

OLI-378 The LDCM OLI shall be capable of entering Instrument Survival Mode without receiving a command from the spacecraft.

Rationale: Survival mode is a power off mode and as such, the instrument may be commanded into this mode without any warning. Clearly, it would be better to have the OLI pass through Safe Mode first but that may not always happen. Direct entry into Survival Mode is not shown in the transition drawing, except from Safe Mode.

OLI-380 The LDCM OLI shall receive no external power from the Operational Power Bus in the Instrument Survival Mode.

Rationale: In this mode, the spacecraft will supply survival heater power but that power does not go through any OLI electronics.

OLI-382 The LDCM OLI shall design and implement survival heaters to ensure the instrument stays within the design, survival temperature range.

Rationale: In this mode, the spacecraft will supply survival heater power but the sizing, and placement of the heaters is the OLI contractors responsibility.

OLI-384 The LDCM OLI shall meet all performance specifications after power up following an indefinite period of time in Instrument Survival Mode.

Rationale: The OLI survival is contingent upon power being supplied to the OLI survival heaters. However, it is the OLI contractor who is responsible for sizing and installing OLI survival heaters.

OLI-1523 Upon exiting OLI Survival Mode, the OLI shall satisfy radiometric stability requirements (i.e. OLI Requirements Document: OLI-1001 and OLI-1003) within 12 hours.

Rationale: The OLI focal plane array and OLI electronics should achieve operational thermal stability within a few hours of exiting survival mode. Achieving radiometric stability requirements within 12 hours of exiting instrument survival is indicative of a thermally well-designed instrument.

OLI-1626 Upon exiting OLI Survival Mode, the OLI shall satisfy geometric performance requirements within a period as specified in Table 5.2-1.

Rationale: Mirrors and telescope structure should withstand survival without the need for heaters. Table values permit designs without structural and mirror survival heaters. The benefits of telescope structure and mirror warming, used solely for speeding recovery from survival, does not offset the design complexity or the necessary increase to the survival power budget. The mirrors, with their significant mass, will set the pace for thermal recovery.

Table 5 - 1 Survival Mode Geometric Recovery Period

Period in Survival Mode	Performance Recovery (not to exceed) [days]
Less than or equal to 1.0 day	1.5
Greater than 1.0 day	9.0

5.2.2 Power-On Mode

OLI-387 The LDCM OLI shall implement a Power-On Mode to transition the instrument during turn-on to its nominal operating state and temperature range.

Rationale: In this low power mode, only those functions required for instrument safety, diagnostics and recovery to full operational status would be powered. The instrument will transition from Survival through Power-On to Safe Mode.

OLI-389 The LDCM OLI Power-On Mode shall terminate by ground command.

Rationale: Power-On Mode includes any deployments and opening of covers or shutters. It is used for the initial power on of the instrument electronics and can be performed while the OLI is at the extremes of the survival temperature range.

OLI-391 The LDCM OLI electronics shall be powered on at any temperature between the cold survival limit and the upper qualification limit.

Rationale: It is possible for power to be applied to the OLI anywhere between the cold survival limit and the upper qualification limit. Application of power at the cold survival limit enables the instrument to achieve its operational temperature range. Nominally, the instrument will not be turned-on at temperatures exceeding the upper operational limit. Note: This requirement is consistent with requirement LEVR-1099 which provides further details on hot and cold temperature turn-on limits.

OLI-393 The LDCM OLI shall use the Power-On Mode to enable the command and telemetry functions, and provide for orderly turn-on based on commands to the instrument.

OLI-394 The LDCM OLI shall transition from Instrument Power-On Mode to Safe Mode within a time period not exceeding one orbit.

Rationale: The OLI transition from Instrument Survival Mode to Safe Mode in as short a time as possible within reason while not damaging the instrument. This is to maximize the availability of the imaging time.

5.2.3 Decontamination Mode

OLI-397 The LDCM OLI shall implement a Decontamination Mode in which the instrument is configured to periodically evaporate contaminants that may have been deposited on critical optical surfaces.

Rationale: The LDCM OLI Decontamination Mode is utilized to outgas and evaporate contaminants from the OLI hardware to prevent contamination from jeopardizing performance. In this mode, initial out gassing during the Launch and Early Orbit Phase will occur.

OLI-399 Upon command, the LDCM OLI shall exercise the Decontamination Mode at any time during the mission.

Rationale: Decontamination of the FPA may be necessary. If so, there should not be any limitations to its use. However, time spent in decontamination is charged against instrument availability.

5.2.4 Operational Mode

OLI-402 The LDCM OLI shall implement an Operational Mode in which all data collection needed to satisfy the full functional and performance requirements for the instrument are performed.

Rationale: This is the nominal operational mode of the instrument. Calibration and off-nadir imaging are nominal operations for the OLI.

OLI-404 The LDCM OLI shall generate the normal image data, instrument housekeeping telemetry, and periodic calibration information while in Operational Mode.

Rationale: All allocated spacecraft resources will be available to the instrument in this mode.

OLI-406 The LDCM OLI shall remain in the Operational Mode without damage while the LDCM Observatory performs orbit correction maneuvers.

Rationale: The instrument is not required to meet performance requirements during orbit correction but is not to be damaged by spacecraft maneuvers.

5.2.5 Diagnostic Mode

OLI-409 The LDCM OLI shall implement a Diagnostic Mode.

OLI-410 The LDCM OLI Diagnostic Mode shall be used when updating or changing the flight software.

OLI-411 The LDCM OLI Diagnostic Mode shall be used to update or make changes to housekeeping telemetry format and content.

The LDCM OLI Diagnostic Mode shall be used to update or make changes to different telemetry sampling rates.

5.2.5.1 Focal Plane Diagnostic Sub-mode

OLI-415 The LDCM OLI shall implement a Focal Plane Diagnostic Sub-mode within the Diagnostics Mode where the output of every physical detector on the OLI focal plane is captured in the image data.

Note: The output of the fully sampled focal plane may be captured at a reduced or sub-sampled rate to accommodate bandwidth constraints.

Rationale: To examine individual outputs from all detectors including those that may normally be combined in time-delay integration (TDI) as well as any redundant detectors. This capability makes it possible to evaluate the status of the focal plane in support of anomaly resolution.

OLI-418 The LDCM OLI Focal Plane Diagnostic Sub-mode shall disable any on-orbit processing operation that combines or compresses raw detector data in any manner.

Rationale: To support early orbit checkout and for anomaly resolution, examples of such processing operations like TDI and compression.

OLI-420 The LDCM OLI Focal Plane Diagnostic Sub-mode shall disable any on-orbit processing operation that normalizes or applies any uniformity correction to detector data in any manner.

Rationale: To support early orbit checkout and for anomaly resolution, example of such processing operations is non-uniformity correction.

5.2.6 Safe Mode

OLI-423 The LDCM OLI shall implement an Instrument Safe Mode in which OLI is in a fully functional configuration without any science data being collected.

Rationale: This is a safe mode of operations where all instrument constraints (thermal, pointing, etc.) are maintained

OLI-425 The LDCM OLI shall autonomously complete transition to its Safe Mode within 45 seconds after receiving the command to enter Safe Mode from any instrument mode in which operational power is applied.

OLI-1623 The LDCM OLI shall autonomously complete safing itself within 75 seconds should the primary means of achieving Safe Mode not be achieved. Note: This duration is from first initiating safe Mode acquisition to completion of safing.

Rationale: OLI-425 places a 45 second limit to Safe Mode acquisition under nominal conditions. This requirement allocates an additional 30 seconds when redundancy or secondary measures are employed.

OLI-426 The LDCM OLI shall transition out of the Power-On Mode or Safe Mode to an operational mode only via ground command.

Rationale: The instrument can transition to safer modes automatically but not up to more complex modes.

OLI-428 The LDCM OLI in Safe Mode shall maintain itself within its design operational temperature limits.

Rationale: This mode maintains operational temperatures and other environment ready for nominal operations.

OLI-430 The LDCM OLI shall autonomously enter into Safe Mode from any mode except the Survival Mode when an OLI detected failure could result in damage to the OLI.

Rationale: The OLI safe mode is enterable from all modes in which operational power is applied to the instrument. Upon detection of a problem, it is expected that OLI can safe itself.

OLI-431 The LDCM OLI shall notify the spacecraft that it has placed itself into the Safe Mode and await specific further commands.

OLI-432 The LDCM OLI shall continue to collect and transmit housekeeping data to the spacecraft when in Safe Mode.

Rationale: Mission or calibration data would not be automatically transferred to the spacecraft, but it could be if commanded to send the data.

OLI-434 The LDCM OLI, while in Safe Mode, shall configure itself such that no damage will occur if the next action from the spacecraft is to turn off the instrument.

Rationale: The contractor may, by choice, utilize this mode as an intermediate state between Operational and Survival Modes.

OLI-436 The LDCM OLI shall enter the Safe Mode by command from the spacecraft.

Rationale: For example this command could be a forwarded ground command, or generated by the spacecraft in response to a power system anomaly. The instrument may also be commanded to enter Safe Mode when the spacecraft is performing scheduled thruster activity, such as for orbit maintenance.

The LDCM OLI shall not over ride or ignore a command to enter Safe Mode.

OLI-442 The LDCM OLI shall enter Safe Mode failing to receive the stored number of consecutive time code data packets from the spacecraft.

Rationale: The OLI will be continuously receiving a time code message unless the S/C C&DH system is down. If the C&DH is down then OLI should be safed.

OLI-444 The LDCM OLI stored number of missed time code packets which result in Safe Mode shall be alterable on-orbit over the range of 1 up to a maximum of 63 consecutive time code data packets.

Rationale: The value selected to enter Safe Mode will depend on instrument and S/C design.

OLI-446 The LDCM OLI shall provide protection against direct solar illumination upon entering Safe Mode.

Rationale: To prevent solar damage to the OLI is about to enter the OLI aperture the instrument would be most protected in Safe Mode

OLI-448 The LDCM OLI shall transition from Instrument Safe Mode to Operational Mode within 7 minutes of command execution.

Rationale: The OLI transition from Instrument Safe Mode to Operational Mode in as short a time as possible within reason to not damage the instrument. This transition should be complete in a single ground contact.

5.3 Data Processing Algorithms

The following section describes the allowable set of data processing algorithms required to make corrections to the OLI image and ancillary data; to detect, evaluate and correct systematic errors in the OLI image and ancillary data; and to use government-provided support data to correct residual errors in the OLI image and ancillary data so that the resulting corrected LDCM data meet the imagery requirements of sections 5.6 and 5.7.

The limitation on data reprocessing is to prevent the use of an open-ended “fix it on the ground” approach that would allow, for example, image-based band registration correction methods. Such methods tend to be highly data dependent making it difficult to verify that performance requirements are met in general rather than only for selected test data sets.

5.3.1 Radiometric Correction Algorithms

The radiometric correction algorithms correct the OLI raw detector sample data, so that the radiometrically corrected OLI image data meet the radiometric performance requirements in sections 5.6.1, 5.6.2.3 and 5.6.5.

5.3.1.1 Detector Bias Determination

OLI-455 The detector bias determination algorithm shall calculate the appropriate bias level for subtraction from each detector for the subsequent conversion to reflectance or radiance.

Note: Historical bias data and/or bias trends, focal plane temperatures, temperature sensitivity coefficients, simultaneous dark detector data, and/or pre and post interval dark image data may be used as necessary for bias determination.

5.3.1.2 Conversion to Radiance

OLI-458 The conversion to radiance algorithm shall take the raw output of each detector in digital numbers and convert it to spectral radiance (W/m^2-sr-µm) using the detector-by-detector bias levels from 5.3.1.1, and previously derived gain coefficients.

Note: Radiometric corrections may include sensitivities to ancillary data, e.g:

$$Gain = C_1 e^{C_2 T}$$

or

$$Gain = C_1 + C_2 X + C_3 Y$$

where C_1, C_2 and C_3 are considered gain coefficients and T, X and Y are ancillary data inputs.

5.3.1.2.1 Conversion to Radiance Algorithm Restrictions

OLI-461 The conversion to radiance algorithm shall not rely on the content of the specific scene being corrected to determine the gain corrections.

5.3.1.3 Conversion to Reflectance

OLI-463 The conversion to reflectance algorithm shall take the raw output of each detector in digital number and convert it to TOA fractional reflectance using the detector-by-detector bias levels from 5.3.1.1, and previously derived absolute and relative gain coefficients.

5.3.1.3.1 Conversion to Reflectance Algorithm Restrictions

OLI-465 The conversion to reflectance algorithm shall not rely on the content of the specific scene being corrected to determine the gain corrections.

5.3.1.4 Inoperable Detector Replacement

OLI-467 The inoperable detector replacement algorithm shall replace the responses from detectors failing to meet the requirements for operability with values estimated from the surrounding detectors.

5.3.1.4.1 Inoperable Detector Replacement Methods

OLI-469 The inoperable detector replacement algorithm shall provide selectable replacement methods including, but not limited to nearest-neighbor replacement and linear interpolation replacement.

5.3.2 Geometric Correction Algorithms

The algorithms which correct for georegistration, geolocation and other geometric effects register radiometrically corrected OLI image data to an absolute Earth coordinate reference system so that the resulting geometrically corrected LDCM data meet the geometric and geolocation performance requirements in section 5.7.

5.3.2.1 Ancillary Data Preprocessing

OLI-473 The ancillary data preprocessing algorithm shall operate on the OLI ancillary data to detect and correct erroneous ancillary data, perform units rescaling and coordinate system conversions, and apply ancillary data calibration corrections (e.g., clock correction, response/transfer function compensation, temperature sensitivity compensation). Auxiliary calibration parameters, quality thresholds, and other reference data sets may be used in this process.

The resulting corrected OLI ancillary data are used by subsequent geometric correction algorithms.

5.3.2.2 Line-of-Sight (LOS) Model Creation

OLI-476 The LOS model creation algorithm shall use preprocessed ancillary data in conjunction with auxiliary calibration parameters to construct a model that relates each OLI pixel line-of-sight to an absolute Earth-referenced coordinate system, such as Earth Centered Inertial of Epoch J2000.

5.3.2.2.1 LOS Model Creation Algorithm Restrictions

OLI-478 The LOS model creation algorithm shall not use image-derived measurements to improve accuracy.

5.3.2.3 Line-of-Sight Projection

OLI-480 The LOS projection algorithm shall use the OLI LOS model in conjunction with the WGS84 G1150 or current version, Earth model to intersect each pixel line-of-sight with the Earth's surface, as defined in the following sections.

5.3.2.3.1 LOS Projection to the Earth Ellipsoid Surface

OLI-482 The LOS intersection algorithm shall intersect each pixel line-of-sight with the WGS84 Earth ellipsoid surface.

5.3.2.3.2 LOS Projection to the Terrain Surface

OLI-484 The LOS intersection algorithm shall intersect each pixel line-of-sight with the Earth's topographic surface as defined by government-furnished digital elevation data accurate to 12 meters (90% linear error).

5.3.2.3.3 LOS Projection Algorithm Restrictions

OLI-486 The LOS intersection algorithm shall not use image-derived measurements to improve accuracy.

5.3.2.4 Line-of-Sight Model Correction

OLI-488 The LOS model correction algorithm shall use measurements of government-provided ground control points in the radiometrically corrected OLI imagery to correct residual systematic errors in the LOS model constructed using the OLI ancillary and calibration data, as described in section 5.3.2.2.

The government-provided ground control points will be accurate to 3 meters (90% circular error) horizontally and 12 meters (90% linear error) vertically, with 5 or more points distributed in the along- and cross-track directions across the WRS-2 scene area.

5.3.2.4.1 LOS Model Correction Algorithm Restrictions

OLI-491 The LOS model correction algorithm shall not use ground reference data beyond that provided by the government.

5.3.3 Image Resampling

OLI-493 The image resampling algorithm shall interpolate at-sensor radiance values for Earth-referenced sample points from the radiometrically corrected OLI image data.

5.3.3.1 Input Image to Resampled Output Image Mapping

OLI-495 The image resampling algorithm shall use the line-of-sight projection algorithms of 5.3.2.3 to geometrically remap the input radiometrically corrected pixels from 5.3.1 to an output Earth-referenced map projection coordinate system.

5.3.3.2 Resampling Interpolation Method

OLI-497 The image resampling algorithm shall use the cubic convolution algorithm [reference 1] for image interpolation.

5.3.4 Data Processing Algorithm Performance

OLI-499 The radiometric correction algorithms of section 5.3.1, the geometric correction algorithms of section 5.3.2, and the image resampling algorithms of section 5.3.3 shall create a radiometrically and geometrically corrected OLI image (all spectral bands) for a WRS-2 scene-sized area, at the nominal ground sample distance for each spectral band, using one commercially available off-the-shelf workstation, in 2 hours or less.

5.4 Spectral Bands

5.4.1 Spectral Band passes

5.4.1.1 Spectral Band Edges

OLI-503 The band edges for each spectral band shall fall within the range of the minimum lower band edge and the maximum upper band edge as listed in Table 5.4-1.

Note: The Full-Width-Half-Maximum (FWHM) points of the relative spectral radiance response curve define the bands edges for each spectral band. The shortest wavelength with 0.5 of peak relative response is the lower band edge; the longest wavelength with 0.5 of peak relative response is the upper band edge.

5.4.1.2 Center Wavelength

OLI-506 The center wavelength of the spectral response, i.e. the mid-point between the band's upper and lower band edges, shall be the values listed in Table 5.4-1 within the specified tolerances also listed in Table 5.4-1.

Table 5 - 2 Spectral Bands

#	Band	Center Wavelength (nm)	Center Wavelength Tolerance (±nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)
1	Coastal Aerosol	443	2	433	453
2	Blue	482	5	450	515
3	Green	562	5	525	600
4	Red	655	5	630	680
5	NIR	865	5	845	885
6	SWIR 1	1610	10	1560	1660
7	SWIR 2*	2200	10	2100	2300
8	Panchromatic **	590	10	500	680
9	Cirrus	1375	5	1360	1390

* Minimum bandwidth is 180 nm for band 7

** Minimum bandwidth is 160 nm for the panchromatic band

5.4.2 Spectral Band Shape

5.4.2.1 Spectral Flatness

5.4.2.1.1 Flatness Between Band Edges

The relative spectral radiance response between the lower band edge (lowest wavelength with 0.5 of peak relative response) and the upper band edge (highest wavelength with 0.5 of peak relative response) is required to have the following properties:

5.4.2.1.1.1 Average Response

OLI-586 The average relative spectral radiance response shall be greater than 0.8.

5.4.2.1.1.2 Minimum Response

OLI-588 No relative spectral radiance response shall be below 0.4.

5.4.2.1.2 Flatness Between 0.8 Relative Response Points

OLI-590 The relative spectral radiance response between the minimum wavelength within the band with a 0.8 relative response point and the maximum wavelength within the band with a 0.8 relative response point shall always exceed 0.7.

5.4.2.2 Out of Band Response

5.4.2.2.1 Beyond 0.01 Relative Response Points

OLI-593 The ratio of the integrated relative spectral radiance response outside the 0.01 response points of each defined spectral band to the integrated relative spectral radiance response between the 0.01 response points of each defined band shall be less than 2%.

Note: The 0.01 relative response points are the points closest to the center wavelength where the relative response first drops to 0.01 of the peak relative response on each side of the center wavelength. The integrated responses will be weighted by the solar TOA irradiance. The MODTRAN 4 “Chkur” solar spectrum will be used for this calculation [reference 2, Section 2.3]. Electrical crosstalk is not included within this requirement.

5.4.2.2.2 Response at Outer Wavelengths

5.4.2.2.2.1 VNIR and Cirrus

OLI-597 For the Visible and Near-Infrared (VNIR), bands 1, 2, 3, 4, and 5, and Cirrus band, band 9, the value of the out of band relative spectral response at wavelengths lower than the lower band edge of the FWHM point minus 50 nm and the wavelengths higher than the higher band edge of the FWHM point plus 50 nm shall not exceed 0.001. Electrical crosstalk is not included within this requirement.

5.4.2.2.2.2 SWIR and Panchromatic

OLI-599 For the two Short-Wave Infrared (SWIR), bands 6 and 7, and Panchromatic band, band 8, the value of the out of band relative spectral response at wavelengths lower than the lower band edge of the FWHM point minus 100 nm and the wavelengths higher than the higher band edge of the FWHM point plus 100 nm shall not exceed 0.001. Electrical crosstalk is not included within this requirement.

5.4.3 Relative Spectral Response Edge Slope

5.4.3.1 Wavelength Intervals - Case 1

OLI-602 The wavelength interval between the first 0.05 and the first 0.5 relative spectral response points and the last 0.5 and the last 0.05 relative response points shall not exceed the values in Table 5.4-2.

5.4.3.2 Wavelength Intervals - Case 2

OLI-604 The wavelength interval between the first 0.01 and the first 0.5 relative spectral response points and the last 0.5 and the last 0.01 relative response points shall not exceed the values in Table 5.4-2.

Table 5 - 3 Spectral Edge Slope Intervals for Reflective Bands

#	Band	Lower Edge Slope Interval 0.01 to 0.50* (nm)	Lower Edge Slope Interval 0.05 to 0.50* (nm)	Upper Edge Slope Interval 0.50 to 0.05* (nm)	Upper Edge Slope Interval 0.50 to 0.01* (nm)
1	Coastal Aerosol	15	10	10	15
2	Blue	25	20	20	25
3	Green	25	20	20	25
4	Red	25	20	15	20
5	NIR	25	20	15	20
6	SWIR 1	40	30	30	40
7	SWIR 2	50	40	40	50
8	Panchromatic	50	40	40	50
9	Cirrus	15	10	10	15

* Normalized to peak spectral response for the band

5.4.4 Spectral Uniformity

OLI-679 Within a band the measured FWHM bandwidths for each detector shall be within ±3% of the measured mean FWHM bandwidth.

Note: Section 5.6.2.3 imposes additional spectral uniformity requirements.

5.4.5 Spectral Stability

OLI-682 Band center wavelengths and band edges shall not change by more ± 2 nm over the life of the mission.

5.4.6 Spectral Band Simultaneity

OLI-684 For any point within a single WRS-2 scene, the OLI shall acquire data for spectral bands 1 through 9 within a 1.5-second period.

5.5 Spatial Performance

5.5.1 Reflective Band Ground Sample Distance

5.5.1.1 Multispectral Bands Pixel-to-Pixel Increment

OLI-688 OLI image data shall provide a pixel-to-pixel increment, in the in-track and cross-track directions, equivalent to a Ground Sampling Distance (GSD) between 28-m up to and including 30-m across the WRS-2 scene for bands 1, 2, 3, 4, 5, 6, 7 and 9 measured at the equatorial crossing.

Rationale: The range of altitude variation at the equator is expected to be within 704 - 706 km.

5.5.1.2 Panchromatic Band Pixel-to-Pixel Increment

OLI-691 OLI image data shall provide a single panchromatic band, band 8, with a pixel-to-pixel increment, in the in-track and cross-track directions, equivalent to a GSD between 14-m up to and including 15-m across the WRS-2 scene measured at the equatorial crossing.

Rationale: The range of altitude variation at the equator is expected to be within 704 - 706 km.

5.5.2 Edge Response

The relative edge response in the in-track and cross-track directions for radiometrically corrected OLI image data, per paragraph 5.3.1.2, shall conform to the criteria described in the following subsections.

Note: Table 5.5-1 lists the bands, their maximum allowable GSD, and the minimum edge slope and maximum half edge extent of the edge response. The edge response, in the context below, is the normalized response of the imaging system to an edge. That is, the edge response is normalized so that the mean low-side steady state edge response is set to zero and the mean high-side steady state edge response is set to 100%.

Table 5 - 4 GSD, Minimum Edge Slope and Maximum Half Edge Extent Specifications

#	Band	Nominal GSD	Minimum Slope	Maximum Half Edge Extent
1	Coastal Aerosol	30 m	.027 / m	23.0 m
2	Blue	30 m	.027 / m	23.0 m
3	Green	30 m	.027 / m	23.0 m
4	Red	30 m	.027 / m	23.5 m
5	NIR	30 m	.027 / m	24.0 m
6	SWIR 1	30 m	.027 / m	28.0 m
7	SWIR 2	30 m	.027 / m	29.0 m
8	Panchromatic	15 m	.054 / m	14.0 m
9	Cirrus	30 m	.027 / m	27.0 m

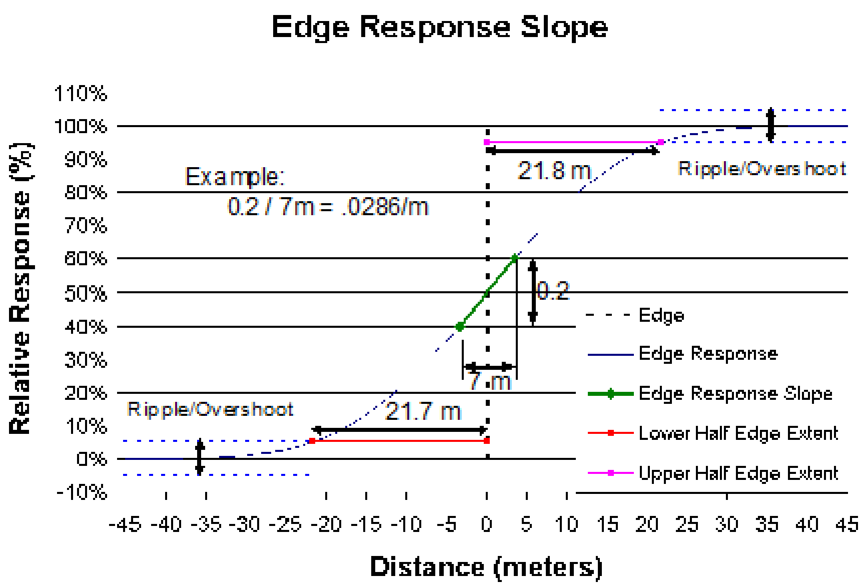


Figure 5 - 2 Relative Edge Response

5.5.2.1 Response Slope

OLI-761 The relative edge response slope for the OLI bands shall exceed the values shown in Table 5.5-1 for radiometrically corrected OLI instrument data, per paragraph 5.3.1.2, across the entire field-of-view.

Note: The relative edge response slope is defined as the slope between the 40% and 60% response points as depicted in Figure 5.5-1.

5.5.2.2 Half Edge Extent

OLI-765 The upper half edge extents and the lower half edge extents for the OLI spectral bands shall be less than the maximum half edge extent values shown in Table 5.5-1 for radiometrically corrected image sensor data, per paragraph 5.3.1.2, across the entire field-of-view.

Rationale: Imaging system simulations have shown that certain types of image degradations (e.g., ghost images with small displacements) can significantly degrade the overall edge response performance even when their effect on the central 40%-60% portion of the edge is minimal. Including a specification that covers more of the edge better protects against this type of localized degradation. The upper and lower half edge extents are both used to protect against artifacts that only effect one side of the edge.

Note: The lower half edge extent is defined as the horizontal distance, in meters, between the 5% and 50% relative response points as depicted in Figure 5.5-1. The upper half edge extent is defined as the horizontal distance, in meters, between the 50% and 95% relative response points as depicted in Figure 5.5-1.

5.5.2.3 Edge Response Overshoot

OLI-769 The overshoot of any edge response for all bands shall not exceed 5% for OLI image data.

Note: Overshoot applies to both the high (100% response) and low (0% response) sides of the edge so that the maximum response is less than 105% and the minimum response is greater than -5%.

5.5.2.4 Edge Response Ripple

OLI-772 Edge response ripple for all bands shall not exceed 5% for OLI image data.

Note: Ripple applies to both the high (100% response) and low (0% response) sides of the edge so that the response is greater than 95% beyond the 95% response point and the response is below 5% beyond the 5% response point.

5.5.2.5 Edge Response Uniformity

OLI-775 The relative edge response slope shall not vary by more than 10% (maximum deviation from the band average) in any band across the field-of-view and by not more than 20% (maximum deviation from the multi-band average) between spectral bands 1, 2, 3, 4, 5, 6, 7, and 9 for OLI image data.

Rationale: This specification ensures consistent spatial performance across the field of view and across the spectral bands to reduce application performance sensitivity to target location within the FOV and control spectral mixing due to spatial effects.

5.5.3 Aliasing

OLI-778 The product of the relative edge response slope and the GSD provided by OLI image data shall be less than 1.0 for both the in-track and cross-track directions.

Rationale: This specification protects against data undersampling by ensuring that the sample spacing (GSD) is commensurate with the actual edge slope performance.

5.5.4 Light Rejection and Internal Scattering

Definition: A light rejection scene or a scene to assess internal light scattering is defined as follows:

- The OLI image data are collected from a circular region having a radius = 0.25 degrees and having a uniform target radiance = LT.
- That target region is surrounded by an annular region having an inner radius = 0.25 degrees and an outer radius = 25 degrees and having a uniform background radiance = LB.
- When LB = LT, the OLI image data radiance measured at the center of the target region has a nominal value = LT.

All angles are measured relative to the OLI nadir view.

OLI-786 The magnitude of the change in the OLI image measured radiance for all spectral bands at the center of the light rejection scene shall be less than 0.004 times the magnitude of the difference between LB and LT, where target and background radiance levels range from a minimum of zero to a maximum of LMax, such that LT - LB ranges from a minimum of -LMax to a maximum of + LMax.

5.5.5 Ghosting

OLI-788 For two dimensional objects with:

- a radiance level at or above 98% of L_{SAT}, and
- located at a position anywhere in the OLI telescope full FOV,

the signal from the object at N pixels away from the object edge shall be less than the values in Table 5.5-2.

Table 5 - 5 Ghosting Requirements

Bands 1-7,9 (30 m Multispectral)	
Distance From Edge (N pixels)	**Maximum Signal**
Between the 5% Relative Edge Response point and 10 pixels	≤ linear threshold from 5% of Lsat to 6.5% of Ltyp at 10 pixels, with Relative Edge Response slope < 0 (i.e. Monotonically decreasing)
Between 10 and 30 pixels	< linear threshold from 6.5% of Ltyp at 10 pixels to 2% of Ltyp at 30 pixels
Greater than 30 pixels	< 2% of Ltyp at > 30 pixels
Band 8 (15 m Panchromatic)	
Distance From Edge (N pixels)	**Maximum Signal**
Between 5% Relative Edge Response point and 20 pixels	≤ linear threshold from 5% of Lsat to 6.5% of Ltyp at 20 pixels, with Relative Edge Response slope < 0 (i.e. Monotonically decreasing)
Between 20 and 60 pixels	< linear threshold from 6.5% of Ltyp at 20 pixels to 2% of Ltyp at 60 pixels
Greater than 60 pixels	< 2% of Ltyp at > 60 pixels

Note: The entire range of N pixels may not be testable for all telescope FOV positions. For example, as the test object moves further off the instantaneous FOV of the active FPA, the closest pixel that can be tested moves further from the edge of the object.

5.6 Radiometry

5.6.1 Absolute Radiometric Uncertainty

OLI-792 The OLI absolute radiometric uncertainty shall be as given in Table 5.6-1 for the range of $L_{typical}$ to 0.9 L_{max} (Table 5.6-2).

OLI-1420 At any other radiance across the range of 0.3 $L_{typical}$ to $L_{typical}$ the absolute uncertainty shall not exceed the values in Table 5.6-1 by more than 0.5%. This requirement applies to extended, spatially uniform, unpolarized targets with a known spectral shape.

OLI-793 Pre-launch radiance uncertainties shall be established relative to National Institute for Standards and Technology (NIST) standards.

OLI-794 Uncertainty estimates shall include the NIST standard uncertainties.

Table 5 - 6 Absolute Radiometric Uncertainty Requirements

Parameter	Requirement (1-sigma)
Radiance	5%
Top of Atmosphere (TOA) Reflectance	3% of actual TOA

Table 5 - 7 Radiance Levels for Signal-to-Noise Ratio (SNR) Requirements and Saturation Radiances

#	Band	Radiance Level for SNR, L (W/m^2 sr µm)		Saturation Radiances, L_{Max} (W/m^2 sr µm)
		Typical, $L_{Typical}$	High, L_{high}	Requirement
1	Coastal Aerosol	40	190	555
2	Blue	40	190	581
3	Green	30	194	544
4	Red	22	150	462
5	NIR	14	150	281
6	SWIR 1	4.0	32	71.3
7	SWIR 2	1.7	11	24.3
8	Panchromatic	23	156	515
9	Cirrus	6.0	N/A	88.5

5.6.2 Radiometric Signal-to-Noise and Uniformity

5.6.2.1 Detector Signal-to-Noise Ratios (SNRs)

OLI-875 The median SNRs required for all OLI image data for each spectral band shall be as listed in Table 5.6-3**.**

OLI-876 50% of all detectors for each band shall meet or exceed these SNR values.

OLI-877 Any detector below 80% of these values shall be considered out-of-specification per paragraph 5.6.7.4.

Table 5 - 8 SNR Requirements

#	Band	SNR Requirements	
		At $L_{Typical}$*	At L_{High}*
1	Coastal Aerosol	130	290
2	Blue	130	360
3	Green	100	390
4	Red	90	340
5	NIR	90	460
6	SWIR 1	100	540
7	SWIR 2	100	510

8	Panchromatic	80	230
9	Cirrus	50	N/A

* - see Table 5.6-2 for definition of $L_{Typical}$ and L_{High}

5.6.2.2 OLI Data Quantization

OLI-936 OLI image data shall be quantized to 12 bits.

OLI image data SNR performance shall not be quantization noise limited at $L_{typical}$ and above, i.e., system noise is greater than or equal to 0.5 Digital Number, unless meeting this requirement would force greater than 12 bit quantization.

5.6.2.3 Pixel-to-Pixel Uniformity

OLI-939 The following environmental conditions and measurement approach shall apply to requirements 5.6.2.3.1, 5.6.2.3.2, and 5.6.2.3.3.

OLI-940 The requirements shall apply for uniform sources with the radiance level above $2{*}L_{typical}$

OLI-941 The radiometric values shall be corrected per paragraph 5.3.1.2.

OLI-942 Temporal noise shall be averaged to verify compliance with this specification.

OLI-943 Target radiances shall have spectral characteristics as follows:

- Spectral radiance from bare desert soil as observed through a dry atmosphere (excluding band 9)
- Spectral radiance proportional to the TOA solar irradiance
- Spectral radiance from a dense vegetation target as observed through a moist atmosphere (excluding band 9)
- These spectral radiances are shown in Figure 5.6-1 and given in “Top of Atmosphere Radiance Values, MODTRAN 4 Model” table values, see GSFC 427-04-01 Top of Atmosphere Radiance Values.

OLI-948 Target radiances shall all be determined using the same gain calibration coefficients.

Note: A pixel column is a consecutive sequence of pixels generated by a single detector.

5.6.2.3.1 Full Field of View

OLI-951 The standard deviation of all pixel column average radiances across the FOV within a band shall not exceed 0.5% of the average radiance.

This requirement is met when:

$$\sqrt{\frac{\sum_{i=1}^{N}(\bar{L}_i - \bar{L}')^2}{N-1}} \leq 0.005 \cdot \bar{L}'$$

Where :

$\bar{L}_i$ is the temporal average response of column i;

$\bar{L}'$ is the 2 dimensiona l (column and line) average response for a spectral band;

N Total number of pixels in a spectral band line.

5.6.2.3.2 Banding

OLI-955 The root mean square of the deviation from the average radiance across the full FOV for any 100 contiguous pixel column averages of radiometrically corrected OLI image data within a band shall not exceed 1.0% of that average radiance.

This banding requirement is met when, for all n:

$$\sqrt{\sum_{i=n}^{n+99}(\bar{L}_i - \bar{L}')^2/100} \leq 0.01 \cdot \bar{L}'$$

Where:

n is the pixel number in a line of data;

$\bar{L}_i$ is the average radiance of pixel column i;

$\bar{L}'$ is the 2 dimensional (column and line) average response for a spectral band.

OLI-962 The standard deviation of the radiometrically corrected values across any 100 contiguous pixels column averages of OLI image data within a band shall not exceed 0.25% of the average radiance across the full FOV.

Note: The average radiance across the FOV is used here merely as a reference for deriving the magnitude of the 0.25%. The mean in the standard deviation calculation is, by definition, the mean of the 100 pixel columns and not the entire FOV mean.

This banding requirement is met when for all n:

$$\sqrt{\sum_{i=n}^{n+99}(\bar{L}_i - \bar{L})^2/99} \leq 0.0025 \cdot \bar{L}$$

Where:

n is the pixel number in a line of data;

$\bar{L}_i$ is the average radiance of pixel column i ;

$\bar{L}$ is the average radiance across the 100 pixel columns

$$\bar{L} = \sum_{i=n}^{n+99} \bar{L}_i / 100$$

$\bar{L}'$ is the 2 dimensiona l (column and line) average response for a spectral band.

5.6.2.3.3 Streaking

OLI-973 The maximum value of the streaking parameter within a line of radiometrically corrected OLI image data shall not exceed 0.005 for bands 1-7 and 9, and 0.01 for the panchromatic band.

The streaking parameter is defined by the following equation:

$$S_i = \left| \bar{L}_i - \frac{1}{2}\left(\bar{L}_{i-1} + \bar{L}_{i+1}\right) \right| / \bar{L}_i$$

Where:

$\bar{L}_i$ is the average radiance of pixel column i;

$\bar{L}_{i-1}$ and $\bar{L}_{i+1}$ are similarly defined for the (i-1)th and (i+1)th pixel columns.

5.6.2.3.4 Temporal Stability

OLI-980 The requirements of section 5.6.2.3.1- 5.6.2.3.3 shall be met for the 7-day period extending forward in time from the calibration update using the same gain calibration coefficients.

Note: Bias determination can be performed during the 7-days per paragraphs 5.3.1.1. Gain calibration coefficients may include a dependency on parameters including instrument temperatures and voltages.

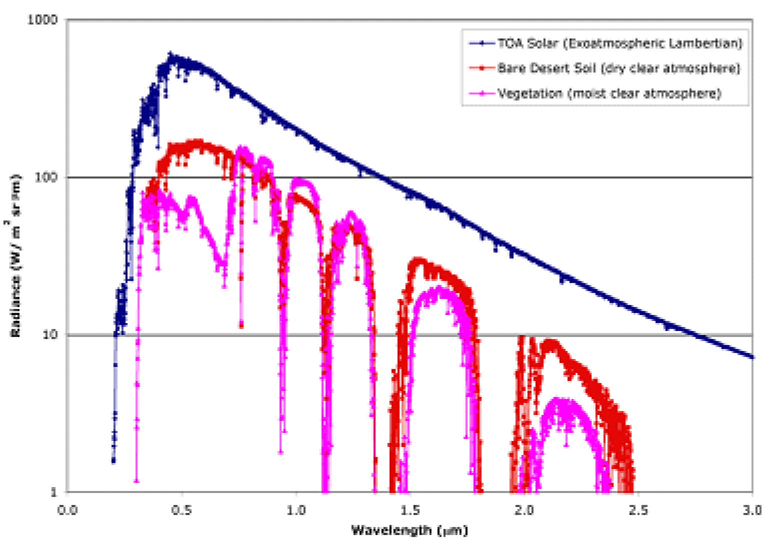


Figure 5 - 3 Top of Atmosphere Spectra for Uniformity Analyses

5.6.2.4 Coherent Noise

OLI-985 Each pixel column in an uniform scene or WRS-2 sized(1) dark background image in any band acquired by the OLI, after radiometric calibration per 5.3.1.2, shall contain coherent noise (CN) components with relative amplitude(2), Arel (in %), not exceeding the maximum amplitude level, Arelmax denoted by the following formula (see Figure 5.6-2):

Arelmax(f) = 9.0 f + 1.5

Where:

f is frequency in cycles/pixel.

Arel is the ratio of an individual CN component zero-to-peak amplitude to the product of 3 times the standard deviation of a full WRS-2 scene and the ratio of the observed median SNR @ Ltypical to the required median SNR @ Ltypical (Table 5.6-3), i.e.

Arel = (Amplitude of Coherent component) / (3 times the standard deviation of the image* SNRObs/SNRReq)*100.

The CN components amplitudes are derived from the average PSD of multiple observations(3) and after frequency domain subtraction of any 1/f noise and the mean white noise floor level. Detectors corresponding to pixel columns are only considered to have failed this requirement, that is, are out-of-specification and subject to the limitations of section 5.6.7.4, if the probability of exceeding Arelmax is greater than 80%.

Notes:

(1) One-half of a WRS-2 is used for the panchromatic band to maintain an equal number of samples with the other bands.

(2) CN component amplitude is the amplitude of the wave pattern generated, for example, in the model of a sine wave it will be the amplitude of a sine wave defined as $A\sin(\omega t + \phi)$.

(3) Multiple collects are used to reduce uncertainty in analysis and establish a frequency dependent threshold (related to standard deviation) to filter out noise spectra peaks that are due to random fluctuations about the noise floor as opposed to coherent noise.

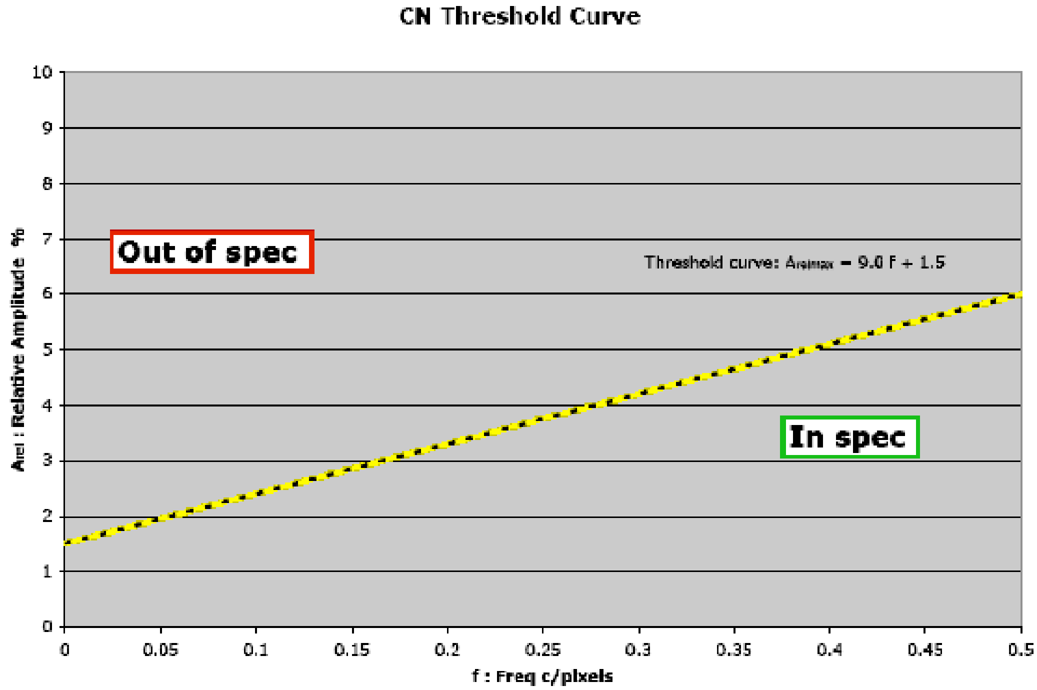


Figure 5 - 4 Coherent Noise Threshold Curve

5.6.3 Saturation Radiances

OLI-996 The OLI shall detect, without saturating, signals up to the L_{max} as shown in Table 5.6-2

Note: For bands 1-8, this corresponds to the radiance reflected off of a Lambertian target of 100% reflectance illuminated by the sun at a solar zenith angle of 22.5°.

5.6.4 Polarization Sensitivity

OLI-999 The OLI polarization sensitivity, as defined by the linear Polarization Factor (PF), shall be less than 0.05, where PF = (Imax-Imin) / (Imax+Imin).

5.6.5 Radiometric Stability

OLI-1001 For Bands 1-8, over any time period up to 16 days, after radiometric correction per 5.3.1.2, with one set of gain coefficients that were determined prior to the 16 day period, the scene averaged OLI image data for radiometrically constant targets with radiances greater than or equal to $L_{-typical}$ shall not vary by more than plus or minus 1% (95% or 2 sigma confidence interval) of measured radiance.

OLI-1522 For Band 9, over any time period up to 16 days, after radiometric correction per 5.3.1.2, with one set of gain coefficients that were determined prior to the 16 day period, the scene averaged OLI image data for radiometrically constant targets with radiances greater than or equal to $L_{\text{-typical}}$ shall not vary by more than plus or minus 2% (95% or 2 sigma confidence interval) of measured radiance.

OLI-1002 Over any time period between 16 days and 5 years, after radiometric correction per 5.3.1.2, the scene-averaged OLI image data for radiometrically constant targets with radiances greater than or equal to $L_{\text{-typical}}$ shall not vary by more than plus or minus 2% (95% or 2 sigma confidence interval) of measured radiance.

OLI-1003 Over any time period up to 60 seconds, after radiometric correction per 5.3.1.2, the scene-averaged OLI image data for radiometrically constant targets with radiances greater than or equal to $L_{\text{-typical}}$ shall not vary by more than plus or minus 0.5% (95% or 2 sigma confidence interval) of measured radiance.

5.6.6 Image Artifacts

5.6.6.1 Bright Target Recovery

OLI-1006 Bright target recovery requirements apply when an image pixel "X" is exposed to a radiance level of up to 1.5 times that of the saturation radiance (Table 5.6-2). Any pixel "Y" outside the 11 x 11 pixel region around image pixel "X" shall not have the "Y" signal changed by more than 1% of its LTypical for bands 1-7 and 9 and shall not have the "Y" signal changed by more than 2% of its LTypical for band 8 as compared to its response when image pixel "X" is exposed to LTypical.

5.6.7 Dead, Inoperable, and Out-of-Spec Detectors

Note: For purposes of assessing detector operability and performance in the case where multiple sensing elements cover the same spatial location, specifically for TDI or detector deselect, the combined effect of the sensing elements will be evaluated as a single detector as noted in the Lexicon. For example, the combined output of the physical detectors summed in TDI will be evaluated as a single detector. In the case of redundant detectors, only the selected active detector will be evaluated.

5.6.7.1 Dead or Inoperable Detectors

OLI-1013 Less than 0.1% of all detectors shall be dead or inoperable.

Note: dead or inoperable detectors may be removed from any performance averages and standard deviations for determining compliance to performance specifications.

5.6.7.2 Dead or Inoperable Detectors per Band

OLI-1016 Less than 0.2% of the detectors in any spectral band shall be dead or inoperable.

5.6.7.3 Adjacent Dead or Inoperable Detectors

OLI-1018 There shall be no across track adjacent dead or inoperable detectors.

5.6.7.4 Out-of-Spec Detectors

OLI-1020 Less than 0.25% of the operable detectors in any spectral band in any WRS-2 scene shall fail to meet one or more performance requirements.

Note: Out-of-spec detectors may be removed from any performance averages and standard deviations for determining compliance to performance specifications.

5.7 Geometric Precision, Geolocation, and Cartographic Registration

The following sections detail the OLI image data geometric accuracy requirements that must be achieved when the correction algorithms provided in accordance with section 5.3 of this specification are applied to OLI image and ancillary data to produce a scene product. The specific correction algorithms that apply to each geometric imagery requirement are shown in table 5.7-1.

Note: End-to-end geometric performance is dependent on the performance of the LDCM spacecraft as well as the OLI. The OLI vendor will be responsible for the end-to-end performance described in this section, assuming spacecraft performance is as specified in the LDCM Observatory Interface Requirements Document (Obs-IRD).

Table 5 - 9 Image Requirement to Processing Algorithm Verification Mapping

	5.3.1 Radiometric Correction	**5.3.2.1 Ancillary Data Processing**	**5.3.2.2 Line-of-Sight (LOS) Model Creation**	**5.3.2.3.1 LOS Projection to WGS84 Ellipsoid Surface**	**5.3.2.4 LOS Model Precision Correction**	**5.3.2.3.2 LOS Projection to Terrain Surface**	**5.3.3 Image Resampling**
5.7.1 Band Registration Accuracy	X	X	X	X	X	X	X
5.7.2 Image Registration Accuracy	X	X	X	X	X	X	X
5.7.3Geodetic Accuracy	X	X	X	X			X

5.7.4 Geometric Accuracy	X	X	X	X	X	X	X

5.7.1 Band-to-Band Registration Accuracy

OLI-1073 Corresponding pixels from the spectral bands in OLI image data that have been geometrically corrected including compensation for the effects of terrain relief shall be co-registered with an uncertainty of 4.5 meters or less in the line and sample directions at the 90% confidence level.

5.7.2 Image-to-Image Registration Accuracy

OLI-1075 Two OLI image data sets of the same area, acquired on different dates, that have been geometrically corrected, including compensation for the effects of terrain relief, shall be co-registered with an uncertainty less than or equal to 12 meters, in the line and sample directions at the 90% confidence level when image-to-image correlation is applied to data from the same spectral band. This requirement applies to data from all spectral bands except band 9.

5.7.3 Geodetic Accuracy

5.7.3.1 Absolute Geodetic Accuracy

OLI-1078 The pixels for targets at the Earth's topographic surface in geometrically corrected LDCM data shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 65 meters (90% circular error), excluding terrain effects. This specification applies to the horizontal error of ground control points measured in the processed image, after compensation for control point height.

5.7.3.2 Relative Geodetic Accuracy

OLI-1080 The pixels for targets at the Earth's topographic surface in geometrically corrected OLI image data shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 25 meters (90% circular error), excluding terrain effects, over a WRS-2 scene, after the removal of constant offsets. This specification applies to the standard deviation of ground control points measured in the processed image, after compensation for control point height.

5.7.4 Geometric Accuracy

OLI-1082 The pixels for targets at the Earth's topographic surface in OLI image data that have been geometrically corrected, including pointing refinement using ground control and terrain compensation using digital elevation data, shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 12 meters (90% circular error), including compensation for terrain effects.

5.8 In-Flight Calibration

OLI-1084 The OLI shall have on-board calibration systems that provide sufficient data with precision and accuracy to meet the calibration and stability requirements of the OLI as described in this document.

5.8.1 Reflective Band Calibration Sources

OLI-1086 Sources for the in-flight calibration shall include celestial objects including both the sun and the moon, and on-board sources such as lamps.

5.8.2 Reflective Band On-board Calibration Systems

OLI-1088 The calibration systems shall at a minimum include:

- A full aperture system, pressed and sintered PTFE (space-grade Spectralon™ or equivalent with existing space flight response characteristics) solar diffuser.
- Control or monitoring of diffuser deployment orientation sufficient to satisfy radiometric requirements.
- A device by which the dark signal of all the detectors can be monitored without requiring non-nominal sensor operations.
- Permanently masked dark detectors for each sensor chip assembly to generate sufficient data to track bias stability during daylight acquisitions for each band.
- A device by which the linearity of the OLI with respect to radiance can be characterized on orbit.
- A source designed to be stable between pre-launch and throughout on-orbit environments.

OLI-1098 The stable source shall be exercised prelaunch and postlaunch to test the transfer to orbit the stability of the OLI.

OLI-1094 The calibration systems shall also include a calibration source with at least three selectable lamp sets, each of which illuminates all detectors and stimulates bands 1-9.

OLI-1410 The lamps shall be operable in constant current mode.

OLI-1411 This lamp-based calibration source shall have an independent optical power output monitor(s).

Note: Use of a single calibration device to meet more than one of the above requirements is not excluded.

OLI-1499 The band-average signal for bands 1-9 from the lamp-based calibration system shall be ≥ 40 counts at the normal Earth imaging integration time.

OLI-1501 The lamp-based calibration system shall warm-up within 4 minutes after lamps turn on.

Definitions and notes applicable to OLI-1503 through OLI-1516: Stability is defined for a single operation over the specified time period. Repeatability is defined as the difference of measurement averages between the specified operation periods. Residual is defined as measurement remaining after the application of corrections for lamp characteristic behavior. Nominal radiance and nominal source illumination assume the lamps are warmed-up for a standard time period and are at operating conditions for temperature and current.

OLI-1503 The residual output stability of the lamp source(s) shall be better than 0.25% (2 sigma) for a period of 60 seconds after lamp warm-up in all OLI bands.

OLI-1504 The output repeatability of the lamp source(s) shall be better than 0.5% (2 sigma) between two 60 second measurements 40 minutes apart assuming a standard warm-up period and 5 minute total operation time for measurement in all OLI bands.

OLI-1505 The output repeatability of the lamp source(s) shall be better than 0.5% (2 sigma) between two 60 second measurements 16 days apart assuming a standard warm-up period and 5 minute total operation time for measurement in all OLI bands.

OLI-1506 The lamp-based calibration system shall include telemetry for sensing voltage and current to allow monitoring of the lamps.

OLI-1507 The lamp-based calibration system voltage sense telemetry shall have an absolute accuracy within ± 1.0%.

OLI-1508 The lamp-based calibration voltage sense telemetry shall have a resolution within 0.02% of nominal voltage.

OLI-1509 The lamp-based calibration system voltage sense output telemetry shall be repeatable within ± 0.05% between two 60 second time periods 40 minutes apart.

OLI-1510 The lamp-based calibration system current sense telemetry shall have an absolute accuracy within ± 1.0%.

OLI-1511 The lamp-based calibration system current sense telemetry shall have a resolution within 0.01% of nominal current.

OLI-1512 The lamp-based calibration system current sense output telemetry shall be repeatable within ± 0.03% between two 60 second time periods 40 minutes apart.

OLI-1513 The independent output power monitor sense telemetry shall have a resolution within ± 0.05% of nominal radiance.

OLI-1514 The residual output stability of the independent optical power output monitor under nominal source illumination shall be better than 0.25% (2 sigma) for a period of 60 seconds.

OLI-1515 The residual output repeatability of the independent optical power output monitor under nominal source illumination shall be better than 0.5% (2 sigma) between two 60 second measurements 40 minutes apart.

OLI-1516 The residual output repeatability of the independent optical power output monitor under nominal source illumination shall be better than 0.5% (2 sigma) between two 60 second measurements 16 days apart.

OLI-1090 The solar diffuser shall be designed to perform calibrations at a solar zenith angle, ($\boldsymbol{\theta}_S$), of no greater than 60° and a view zenith angle, ($\boldsymbol{\theta}_V$), of no greater than 48°, see Figure 5.8-1.

OLI-1091 The solar diffuser shall be protected from solar illumination when not in use.

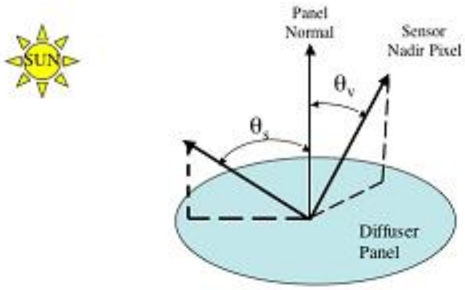


Figure 5 - 5 Diffuser Panel Relative Geometry

6 Structural and Mechanical Systems

OLI-1101 The LDCM OLI structure shall be of sufficient strength and stiffness to maintain structural integrity and withstand all ground testing, handling, transportation, launch, launch vehicle separation, and mission orbit environments.

OLI-1102 The LDCM OLI shall provide a fixed-base fundamental resonant mode frequency of greater than 40 Hz for both launch and on-orbit configurations.

Rationale: A value of 40 Hz should provide adequate margin for the launch vibration environment as well as the on-orbit disturbance environment.

OLI-1106 The LDCM OLI structure shall provide structural support and orientation to the focal plane array, optical telescope, and electronics assemblies.

OLI-1107 The LDCM OLI structure shall provide a mounting interface for the OLI to the LDCM Spacecraft.

OLI-1108 The LDCM OLI structural and mechanical interface shall accommodate manufacturing tolerance, structural, and thermal distortions.

OLI-1109 The LDCM OLI structural system shall provide an external optical alignment device.

Rationale: The OLI instrument needs to be co-aligned with the spacecraft inertial reference system and with the Thermal InfraRed Sensor.

OLI-1111 The LDCM OLI mechanical alignment device's orientation relative to the OLI optical axis shall be known to an accuracy of 600 micro-radians, 3-sigma for each axis.

Rationale: The alignment device (cube) will be used to determine the prelaunch alignment between the OLI optical axes and the spacecraft attitude determination reference system. Thus, knowledge of the alignment between the cube and the OLI optical system is necessary to determine the relationship between the OLI boresight and the spacecraft coordinate system during prelaunch alignment measurements. Since the OLI to attitude determination system alignment is likely to change somewhat at launch due to launch shift and zero-G release, this alignment will also be ascertained on-orbit. The accuracy of the prelaunch measurement is thus not critical for geolocation accuracy but is needed to ensure proper alignment of the instrument(s) and attitude sensors and to initialize the on-orbit calibration procedure.

OLI-1113 The LDCM OLI focal plane to optical axis mechanical alignment shall be internally stable to less than 6 micro-radians, 3-sigma for each axis over the full thermal operational design temperature range over each 16-day observation cycle.

Rationale: The internal alignment stability of the OLI instrument is the single most critical mechanical design challenge. Stability induced alignment errors can not be backed out of the on-orbit calibration data. Focal plane to optical axis stability is needed to ensure that the relationships between detector lines of sight within the OLI field of view remain sufficiently consistent to ensure accurate band-to-band registration.

OLI-1115 The LDCM OLI optical axis to mounting interface mechanical alignment shall be stable to less than 12 micro-radians, 3-sigma for each axis over the full thermal operational design temperature range during each 16-day observation cycle.

Rationale: Stability of the OLI optical system's pointing relative to the spacecraft attitude determination system is necessary to ensure accurate geolocation. The stability of the OLI optical system's alignment relative to the OLI mounting interface is one component of this overall alignment stability.

OLI-1117 The LDCM OLI mechanical system shall provide a gaseous purge fitting.

Rationale: To allow a positive dry nitrogen or dry air gas purge within the OLI during all stages of instrument and satellite integration, test, shipment, launch site processing, and while on the launch pad up to T-0.

OLI-1119 The LDCM OLI shall use an optical reference coordinate system that is defined as a right-hand, orthogonal, body fixed, XYZ coordinate system with the +Z axis aligned with the OLI instrument optical axis and the origin and coordinate system documented in the OLI to Spacecraft Interface Control Document.

Rationale: This orientation provides that when the observatory is in a nominal earth pointing attitude, the +Z axis points towards the Earth sub-satellite point.

OLI-1121 The LDCM OLI shall provide access to all telescope optical surfaces during Integration and Testing (I&T) without disturbing alignment that would require telescope performance revalidation.

Rationale: Access may be needed to clean the telescope optical surfaces without major sensor system disassembly or de-integration from the OLI GSE or de-integration of the OLI from the spacecraft bus.

7 Thermal Control

OLI-1124 The LDCM OLI shall be thermally safe for continuous operations in all modes.

Rationale: The OLI design and operation needs to be thermally safe when in Survival Mode assuming power is provided by the spacecraft and in all other modes with power distributed by OLI.

OLI-1126 The LDCM OLI shall maintain its subsystems within their survival temperature range when the OLI is in Survival Mode when the spacecraft supplies power to survival heaters.

Rationale: During Observatory Safe Hold the observatory subsystems including instruments are allowed to thermally drift in order to minimize power consumption.

OLI-1128 The LDCM OLI shall maintain subsystems within their design operational temperature range for nominal operational modes except for Decontamination Mode.

Rationale: During de-contamination of the FPA or other elements it is conceivable that components could exceed their design operational temperatures but not their survival temperatures.

OLI-1130 The LDCM OLI precision temperature control shall be located within the OLI, provided by OLI, controlled by the instrument electronics and use power from the overall OLI power budget.

The LDCM OLI shall keep the imaging sensor thermally stable over a 16-day observation period within its design temperature range, while in the operational modes.

OLI-1133 The LDCM OLI operational thermal range shall be reprogrammable on orbit.

OLI-1134 The LDCM OLI survival heaters shall be on a power circuit independent of the OLI instrument.

Rationale: OLI survival heaters must be powered when the rest of the OLI is powered off. Survival heaters are assumed on while OLI is in the Survival or Off Mode.

8 Electrical System

OLI-1137 The LDCM OLI shall provide protection from over voltage and under voltage conditions for power coming into the instrument.

OLI-1138 The LDCM OLI shall not be damaged by the application of bus voltages between 0 and 35 volts direct current.

Rationale: Low voltage startup should not damage the instrument, it may not start up but it will not break.

OLI-1140 The LDCM OLI shall be designed to operate from a 28 +/- 7 volt direct current.

OLI-1143 The LDCM OLI shall physically isolate all power lines from signal lines.

Rationale: To protect communication circuits from high voltage OLI should use shielded and separate cables.

9 Flight Software

9.1 General

OLI-1147 The LDCM OLI flight software shall be reprogrammable on orbit, excluding firmware (FPGAs and ASICs).

Rationale: This requirement is not intended to have embedded flight software in FPGA or permanently code state machines changed on-orbit.

OLI-1149 The LDCM OLI shall possess sufficient non-volatile memory to contain two entire copies of the OLI flight software image at launch.

OLI-1150 The LDCM OLI shall monitor flight software tasks or functions to detect for infinite loops or “hung” processes.

OLI-1151 The LDCM OLI flight software shall protected against SEUs and other memory and processor errors.

Rationale: This can be done through the use of design features such as memory error detection and correction (EDAC), periodic software refresh of critical hardware registers, processor and register majority voting, watchdog timers, etc.

OLI-1153 The LDCM OLI flight software shall verify the validity of all memory areas.

Rationale: To ensure that valid data/ instructions, etc. are in use. This task should run with a high enough frequency to fix environment induced bit flips.

OLI-1155 The LDCM OLI flight software shall detect and correct single bit memory errors.

Rationale: Because bit flips happen.

OLI-1157 The LDCM OLI flight software shall detect and report multiple bit errors in memory.

Rationale: Because bit flips happen and not all errors can be corrected.

OLI-1159 Upon command, the LDCM OLI flight software shall monitor and report the resource utilization by software subsystems or critical functions.

Rationale: This ensures that margins are maintained over the development life of the software.

OLI-1161 The LDCM OLI flight software shall make resource utilization monitors available for downlink in telemetry.

Rationale: To verify functions are running smoothly and with expected CPU utilization.

OLI-1163 The LDCM OLI flight software tasks shall have a defined execution priority.

Rationale: Because critical tasks need to execute before non-critical tasks.

OLI-1165 The LDCM OLI flight software shall store the version identifier of reprogrammable software onboard.

OLI-1166 The LDCM OLI firmware shall store the version identifier of the embedded software onboard.

OLI-1167 The LDCM OLI flight software shall maintain a mapping of table name to memory address location.

OLI-1168 The LDCM OLI flight software shall update any and all memory table locations through command table names.

OLI-1169 The LDCM OLI flight software shall load any location of on-board memory by referencing its physical memory address.

OLI-1170 Upon command, the LDCM OLI flight software shall dump any location in program memory.

Rationale: This supports debugging efforts and provides additional telemetry points which may have been unanticipated at development time.

OLI-1172 Upon command, the LDCM OLI flight software shall dump the entire memory of on-board processors.

Rationale: This supports debugging efforts and provides telemetry on the state of the on-board flight software.

OLI-1174 The LDCM OLI flight software memory dump operation shall not disturb nominal execution of the flight software.

Rationale: This requirement is not to effect the on-going observatory operations or software processes. This requirement should only effect (replace or supplement or use excess wideband data) capability to get the memory dump telemetry on the ground.

OLI-1176 The LDCM OLI shall implement independent time-based (watch-dog timer) monitoring circuits.

Rationale: On-board processors should use hardware "watch dog" timers, or some hardware implemented system independent of the CPU to interrupt stuck software.

9.2 Event Logging

OLI-1179 The LDCM OLI flight software shall time tag events logged in telemetry with an accuracy less than or equal to 250 milliseconds.

Rationale: A reported event would contain information on the source processor, flight software task or function, severity level, message identifier and informational string that identifies the cause. The event messages capture anomalous events, redundancy management switching of components and important system performance events and warm and cold restarts to the accuracy of command execution.

OLI-1181 The LDCM OLI flight software shall report all event messages in the observatory housekeeping telemetry.

9.3 Initialization

OLI-1183 The LDCM OLI shall preserve contents of a processor event log after a cold restart.

9.3.1 Cold Restart

OLI-1185 The LDCM OLI shall execute a cold restart of a processor's software from Read Only Memory in response to a ground command.

Rationale: This is a reboot of the flight software instruction set loaded from the non-volatile on-board memory (EEPROM, PROM, etc.) and does not require a power-on reset.

OLI-1187 The LDCM OLI flight software shall execute a Cold Restart initialization process when starting execution from a hardware reset.

OLI-1188 The LDCM OLI flight software shall execute a restart of a processor's software from Read Only Memory following a power cycle or hardware reset.

Rationale: This is a complete reboot of the flight software loaded from the non-volatile on-board memory (EEPROM, PROM, etc.).

OLI-1190 The LDCM OLI flight software shall default to a known telemetry configuration following a Cold Restart.

OLI-1620 Upon receipt of a valid Cold Restart command, the OLI flight software shall restart within 10 seconds.

Rationale: Placement of a 10 second limit for cold restart completion accomplishes the primary goal of a warm restart; i.e. a rapid boot-up and permits compliance with OLI-425, attainment of instrument safe mode within 45 seconds.

9.4 Failure Detection, Protection and Correction

OLI-1196 The LDCM OLI shall automatically detect and report in telemetry hardware and software out of limit and fault conditions.

OLI-1197 The LDCM OLI subsystems that perform self-diagnostics shall report the results in a diagnostic telemetry stream.

Rationale: Diagnostic data should be made available on the ground through special telemetry formats that are tailored for debugging and diagnostics.

OLI-1199 The LDCM OLI subsystems that support self-diagnostics shall accept ground commands to run diagnostics and report the results as an event.

Rationale: Flexibility is necessary to support debugging conditions that may not be known until after launch.

OLI-1201 The LDCM OLI shall reject invalid commands.

OLI-1202 The LDCM OLI shall report rejected commands in housekeeping telemetry.

9.5 Hardware Commands

OLI-1204 The LDCM OLI watchdog timer shall be enabled or disabled by a hardware pulse command.

Rationale: Flexibility is necessary to support debugging conditions that may not be known until after launch.

OLI-1206 The LDCM OLI onboard processor(s) shall reset upon receipt of a hardware pulse command(s).

Rationale: Flexibility is necessary to support debugging conditions that may not be known until after launch.

10 Command & Data Handling

10.1 General

The LDCM OLI shall maintain its instrument health and its safe operation without ground support.

OLI-1212 The LDCM OLI shall continuously monitor its health and safety.

OLI-1213 The LDCM OLI shall report the health and safety of the OLI components to the spacecraft.

OLI-1214 The LDCM OLI shall time tag OLI instrument data with an accuracy relative to the LDCM Observatory time reference of 100 microseconds or less, 3-sigma.

Rationale: To ensure that the image data can be synchronized with the ancillary data the two time references should be accurate to each other within 50µsecs. The LDCM OLI will receive a one pulse per second from the LDCM spacecraft for time synchronization.

OLI-1216 The LDCM OLI reference time shall be accurate to within 50 microseconds or less, 3-sigma of each LDCM spacecraft 1-second timing pulse.

OLI-1217 The OLI shall incur no more than one uncorrectable/uncorrected error in 10^13 bits per 24 hour period.

Rationale: The bit error rate is to limit the number of bad bits prior to transfer to the downlink interface.

10.2 Data Compression and Non-uniformity Correction

If the LDCM OLI implements compression of data, then the requirements of section 11.2.1 shall apply.

If the LDCM OLI implements non-uniformity correction on the image data then the requirements of section 11.2.2 shall apply.

10.2.1 Image Data Compression

The LDCM OLI data compression algorithm applied to OLI image data or ancillary data shall be lossless.

The LDCM OLI data compression algorithm shall be commandable on and off.

10.2.2 Image Data Non-Uniformity Correction (NUC)

The LDCM OLI NUC algorithm implemented shall be fully reversible.

The LDCM OLI NUC algorithm implemented shall have reconfigurable coefficients to allow for updates.

The LDCM OLI shall record and transmit the NUC coefficients used with each image data file.

The LDCM OLI shall receive and implement updated NUC coefficient data.

10.3 Telemetry

OLI-1235 The LDCM OLI shall provide sufficient telemetry to ensure proper control and monitoring of OLI health and safety, and to identify anomalous conditions.

Rationale: For proper insight into the state of health and on going instrument activities, memory dumps, housekeeping data, etc.

The LDCM OLI shall partition the MIL-STD-1553 telemetry into two groups, with each group contained within a contiguous range of 1553 subaddresses. The two groups are:

1. Telemetry needed during spacecraft maneuvers.
2. Telemetry needed for calibration/validation.

All other 1553 telemetry may be placed anywhere within the telemetry subaddresses allocated to OLI.

The LDCM OLI shall select one of the available telemetry stream definitions from onboard storage upon a single command.

OLI-1240 The LDCM OLI shall report the command identifier in housekeeping telemetry when executed.

Rationale: When OLI executes a command this information should be written off into the HK telemetry.

OLI-1242 The LDCM OLI shall generate and transmit real-time instrument housekeeping data to the LDCM spacecraft.

Rationale: Real-time HK data is needed to monitor and control the instrument.

10.4 Command Capability

OLI-1245 The LDCM OLI shall accept and execute discrete and hardware pulse commands in real time only.

OLI-1246 The LDCM OLI shall process real-time commands while concurrently executing long-duration commands.

Rationale: Commands such as on-board processor uploads, imaging may take several minutes and once these processes have started the instrument should be able to continue processing normal functions.

OLI-1248 The LDCM OLI shall receive flight software loads with a duration that extends across one or more ground station contacts.

OLI-1249 The LDCM OLI shall receive flight software updates by patches at the function, unit, or module level.

OLI-1250 The LDCM OLI shall validate, process, and execute commands and data loads.

OLI-1251 The LDCM OLI shall not execute a command that has failed validation.

OLI-1252 The LDCM OLI shall report commands that fail validation in housekeeping telemetry.

OLI-1253 The LDCM OLI shall have no command lockout.

Rationale: There is no command to lock-out or permanently disable the OLI instrument

The LDCM OLI shall access information from any data tables stored in onboard RAM through a single command.

The LDCM OLI shall load a parameter of any table without loading the entire table.

OLI-1257 The LDCM OLI real-time command shall perform only one function, fully identified in the command data field establishing a known state and condition.

Rationale: Using toggle commands can leave the state of a switch, box, etc. unknown. It is better to have enables and disables be unique commands and not just toggle back and forth. A toggle commands would not be permitted as they do not fully define the final state.

OLI-1259 The LDCM OLI shall execute a command at a frequency of at least 4 Hz.

OLI-1260 The LDCM OLI shall begin command execution within 250.0 milliseconds from the time the valid command is received by OLI.

Rationale: To prevent undue delay in execution of commands that may lead to unpredictable operation.

11 System Margins

11.1 Technical Resource Margins

OLI-1263 The LDCM OLI shall use the following equation for margin calculations:

Margin (in percent) = 100% x (Allocated Resource - Estimated Resource) / Estimated Resource.

OLI-1266 The LDCM OLI shall include required performance margins to ensure requirements are met at end of design life.

Rationale: Sufficient performance margins must exist at launch to provide for nominal performance in systems at end of the design life. Therefore, items such as SNR, power consumption, reflective surfaces, etc. degrade with time.

OLI-1268 The LDCM OLI shall have technical resources margins by component development phase as defined in Table 12-1 and Table 12-2. in excess of the design specifications defined by the design life time requirements at the end of a component's development phase:

Table 11 - 1 Technical Resource Margins by Development Phase

Resource	Contract ATP	I-Sys Req Review (Phase A)	Preliminary Design Review (Phase B)	Critical Design Review (Phase C)	Pre-Environmental Design Review (Phase D)
Mass	>30%	>25%	>20%	>15%	5%
Power wrt End of Design Life Allocation	>30%	>25%	>15%	>15%	>10%*
Telemetry and Command Hardware Channels **	>25%	>20%	>15%	>10%	2%

** Telemetry and command hardware channels transfer data between hardware such as thermistors, heaters, switches, motors, detectors, etc. and controller electronics and between pairs of controller electronics.

OLI-1301 The LDCM OLI flight software shall have the following minimum resource margins at the end of each development phase per processor:

Table 11 - 2 Flight Software Processing Margins by Development Phase

Resources	I-Sys Req Review	Preliminary Design	Critical Design	Pre-Environmental

	(Phase A)	**Review (Phase B)**	**Review (Phase C)**	**Design Review (Phase D)**
Central Processing Unit Utilization	50%	50%	40%	30%
Central Processing Unit Deadlines	50%	50%	40%	30%
Programmable Read-Only Memory	50%	30%	20%	5%
Electrically Erasable Programmable Read-Only Memory	50%	50%	40%	30%
Random Access Memory	50%	50%	40%	30%
Peripheral Component Interconnect (PCI) bus	75%	70%	60%	50%
1553 bus	30%	25%	20%	10%
Universal Asynchronous Receiver-Transmitter (UART)	50%	50%	40%	30%
Observatory Command Bus Throughput	50%	50%	40%	30%
LVDS	50%	50%	40%	30%

12 Verification Cross Reference Matrix (VCRM)

13 Appendix A

14 Appendix B

15 Appendix C